Kokanee Stock Status and Contribution of Cabinet Gorge Hatchery Lake Pend Oreille, Idaho

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KOKANEE STOCK STATUS AND CONTRIBUTION OF CABINET GORGE HATCHERY
LAKE PEND OREILLE, IDAHO

Annual Progress Report FY 1989

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ABSTRACT

The kokanee Oncorhynchus nerka rehabilitation program for Lake Pend Oreille continued to show progress during 1989. Estimated kokanee abundance in late August was 7.71 million fish. Even though abundance was 24% lower than 1988, it was 80% higher than the population's low point in 1986, and the second highest since the completion of Cabinet Gorge Hatchery in 1985. Decreased population size is the result of lower hatchery and wild fry recruitment and low age 1+ survival. Lower recruitment of wild fry in 1989 resulted from a smaller parental escapement in 1988 and lower wild fry survival.

Hatchery fry made up 50% of total fry recruitment (80% of total fry biomass), which is the second largest contribution since hatchery supplementation began in the 1970s. High hatchery fry abundance resulted from a large release (11.7 million fry) from Cabinet Gorge Hatchery in 1989, and good fry survival (19%) during their first summer in Lake Pend Oreille. Improved fry release strategies enhanced survival, which was seven times higher than survival in 1986 and approximately 35% higher than 1987, but 40% lower than 1988. Replication of releases in 1989 indicated that fry survival from release to fall sampling may range between 20% and 30%. The management goal is to attain 30% survival.

Six fry release strategies were evaluated in 1989. Two groups were released in Clark Fork River to help improve a spawning run to Cabinet Gorge Hatchery. High river flows of 1,000 m^3/s (36,000 ft^3/s) during the early release (June) helped flush fry quickly to Lake Pend Oreille and doubled survival (18%) over previous releases during lower flows of 570 m^3/s (20,000 ft^3/s) or less. Survival from the mid-summer release (16%), which was barged down Clark Fork River to avoid low flow problems, was not significantly different ($P>0.10$) from the early release. The final assessment of these release strategies will be evaluated when adults return to Cabinet Gorge Hatchery in 1992 and 1993. Fry released to support the Sullivan Springs Creek spawning run also survived well (21%) in 1989. Two open-water releases were made during early and mid-summer. The early release had the lowest survival (5%) of all strategies and was significantly lower (P(0.10) than any other releases. Lower survival may have been attributed to a lack of cladoceran and size of fry released. The mid-summer release did have high survival (25%), which may have been due to abundant forage and low predation. Shoreline releases of fry in southern Lake Pend Oreille had the highest survival (27%), which was probably due to abundant forage.

The fishery and egg-take should rebound slightly in 1990 as a relatively strong 1986 year-class matures. Effects of the rehabilitation program may be evident by 1991, when the first strong year-classes produced from Cabinet Gorge Hatchery enter the sport fishery and spawning escapement.

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INTRODUCTION

Lake Pend Oreille supported the most popular kokanee salmon Oncorhynchus nerka fishery in Idaho from the 1940s until the early 1970s. The sport and commercial fishery yielded an average annual harvest of one million kokanee and 360,000 hours of angling effort from 1951 to 1965 (Ellis and Bowler 1979). Sport anglers enjoyed average annual catch rates as high as 3.5 fish/h during the mid-1960s. Kokanee harvest declined from 1965 to 1985, resulting in an annual harvest of less than 100,000 fish, with a mean catch rate of approximately 1.0 kokanee/h (Bowles et al. 1987). Management goals for the kokanee rehabilitation program include an annual harvest of 750,000 kokanee averaging 25 cm long and catch rates averaging 2.0 fish/h. In addition to providing an important fishery, kokanee are the primary forage for trophy Kamloops (Gerrard) rainbow trout Oncorhynchus mykiss and bull trout Salvelinus confluentus in Lake Pend Oreille.

Several factors contributed to the initial decline of kokanee abundance. Hydropower development adversely impacted spawning success of kokanee salmon. Albeni Falls Dam was completed in 1952 by the Army Corps of Engineers as part of the Bonneville Power Administration (BPA) network. Located on the Pend Oreille River, approximately 35 km downstream of Lake Pend Oreille, Albeni Falls Dam raised lake levels by 4 m. Annual winter drawdown, which averaged 1.3 m from 1951 to 1968, increased embryo mortality by exposing redds of lakeshore-spawning kokanee (Bowler et al. 1979). Cabinet Gorge Dam was constructed on the Clark Fork River (river km 24) for power generation by Washington Water Power Company (WWP). Completion of this dam in 1952 blocked an important kokanee spawning run into Clark Fork River and its tributaries. Declining kokanee abundance may have been accelerated by commercial and sport fishing. The establishment of opossum shrimp Mysis relicta in Lake Pend Oreille during the mid-1970s adversely impacted kokanee recruitment. Idaho Department of Fish and Game (IDFG) introduced Mysis in 1966 to enhance the kokanee forage base. The expected response of increased kokanee growth and survival did not occur because mysids competed with postemergent kokanee fry for cladoceran zooplankton. Competition with, and predation on, zooplankton by mysids delayed production of two cladocerans (Daphnia and Bosmina) that are essential juvenile kokanee forage during the first few weeks of feeding (Rieman and Bowler 1980). Increased growth of older kokanee did not occur because of spatial segregation between Mysis and feeding kokanee. Mysids remain in deep water during daylight hours and migrate to surface waters at night. Kokanee are visual feeders and are thus able to feed on the shrimp for short periods at dawn and dusk (Rieman 1977).

Interagency efforts to rehabilitate the kokanee fishery began during its initial decline. In 1967, the Army Corps of Engineers adopted a policy for operation of Albeni Falls Dam to minimize water level fluctuations during kokanee spawning and incubation. IDFG restricted kokanee sport harvest and terminated the commercial fishery in 1973. Hatchery production of kokanee for Lake Pend Oreille was established by 1974 and helped stabilize population numbers. Delayed planting of hatchery fry until mid-summer to avoid early season forage deficiencies increased hatchery fry survival up to 13 times over wild fry (Bowler 1981). Hatchery production kept the fishery from total collapse, but rearing capacity of existing hatcheries was inadequate to rebuild the fishery. Prior to 1985, hatcheries could provide only 6 to 8 million kokanee fry annually for Lake Pend Oreille. Releases of up to 20 million fry annually may be necessary to restore the fishery to historic levels (Rieman 1981).

In an effort to enhance Lake Pend Oreille kokanee production, Cabinet Gorge Hatchery was built on the Clark Fork River 4 km below Cabinet Gorge Dam. Cost of the hatchery was approximately $2.2 million and represented a cooperative effort among BPA, WWP and IDFG. BPA funding was from on-site resident fish mitigation funds mandated by the Northwest Power Act of 1980. Construction and evaluation of Cabinet Gorge Hatchery is specified by Measure 804(e)(5) of the Columbia River Basin Fish and Wildlife Program (NWPPC 1984). Cabinet Gorge Hatchery was operational by November 1985, and, at full capacity, will provide up to 20 million kokanee fry for release into the Pend Oreille system. Rebuilding the kokanee population to attain the goal of over 750,000 kokanee harvested annually and 300,000 hours of effort will depend on production from this hatchery.

This research project was developed by IDFG in cooperation with BPA and WWP to evaluate the contribution of Cabinet Gorge Hatchery to the Lake Pend Oreille kokanee stock and fishery and to provide recommendations for optimizing kokanee production and survival. BPA provided the majority (>90%) of funding for this project. Funds from WWP were used for the fry marking study that examined the feasibility of differentially marking kokanee release groups. WWP also provided funding assistance for evaluating kokanee fry release strategies, which included providing requested discharge flows from Cabinet Gorge Dam.

OBJECTIVES

1. To monitor the kokanee population in Lake Pend Oreille as production increases from Cabinet Gorge Hatchery, *including* population size, age composition, and hatchery-wild composition.

2. To monitor changes in kokanee age composition, growth and survival in relation to population density, and carrying capacity of Lake Pend Oreille.

3. To evaluate kokanee release strategies by estimating kokanee fry emigration rate, timing and survival with respect to river discharge, diel timing, moon phase, release site, fish size, and number of fry released.

4. To determine feasibility of differentially marking fry release groups by evaluating retention and mortality associated with various marks.

5. To obtain index information on natural spawning kokanee to monitor contribution of hatchery-reared fish.

6. To monitor the zooplankton community in Lake Pend Oreille and relate to changes in kokanee abundance.

STUDY AREA

Lake Pend Oreille is located in the panhandle of Idaho (Figure 1). It is the largest lake in Idaho, with a surface area of 383 km^2, mean depth of 164 m, and maximum depth of 351 m. Mean surface elevation of Lake Pend Oreille is 629 m. The Clark Fork River is the largest tributary to Lake Pend Oreille. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. Summer temperatures (May to October) average approximately 9°C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. The N:P ratio is typically high (>11) and indicates primary production may be P limited (Rieman and Bowler 1980). Mean chlorophyll "a" concentration during summer is approximately 2 micrograms/L. Summer mean water transparency (Secchi disk) ranges from 5 to 11 m.

A wide diversity of fish species are present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s, presumably from Flathead Lake, and were well established by the 1940s. Other game fish include: Kamloops (Gerrard) rainbow trout, bull trout, rainbow trout *Oncorhynchus mykiss*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, lake whitefish *Coregonus clupeaformis*, mountain whitefish *Prosopium williamsoni*, and several spiny ray species.

METHODS

Kokanee Population Structure

Kokanee population structure in Lake Pend Oreille was determined from fish collected with a mid-water trawl during the last week of August. Fish from each sample were counted, measured, weighed, and checked for maturity. Sagitta otoliths were excised for aging. The mid-water trawl was towed by a 8.5 m boat powered by a 140-hp diesel engine. The net was 13.7 m long with a 3 x 3 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. All age-classes of kokanee were collected. Trawling was done at night during the dark phase of the moon to optimize capture efficiency (Bowler 1979). The trawl was towed at 1.5 m/s at depths calibrated with sonar. Each oblique haul sampled the entire vertical distribution of kokanee, as determined from echograms produced by a Ross 200 angstrom depth sounder with two hull-mounted transducers (22° and 8° beam angles). The vertical distribution of kokanee was divided into 3.5 m layers; usually 3 to 5 layers encompassed the vertical distribution of kokanee. A standard 3.5 min tow was made in each layer, sampling 2,832 m^3 of water over a distance of 305 m. Total volume of water sampled for each trawl haul varied from 8,496 to 16,992 m^3, depending on the vertical distribution of kokanee.

A stratified systematic sampling scheme was used to estimate kokanee abundance and density. Lake Pend Oreille was divided into six sections or strata

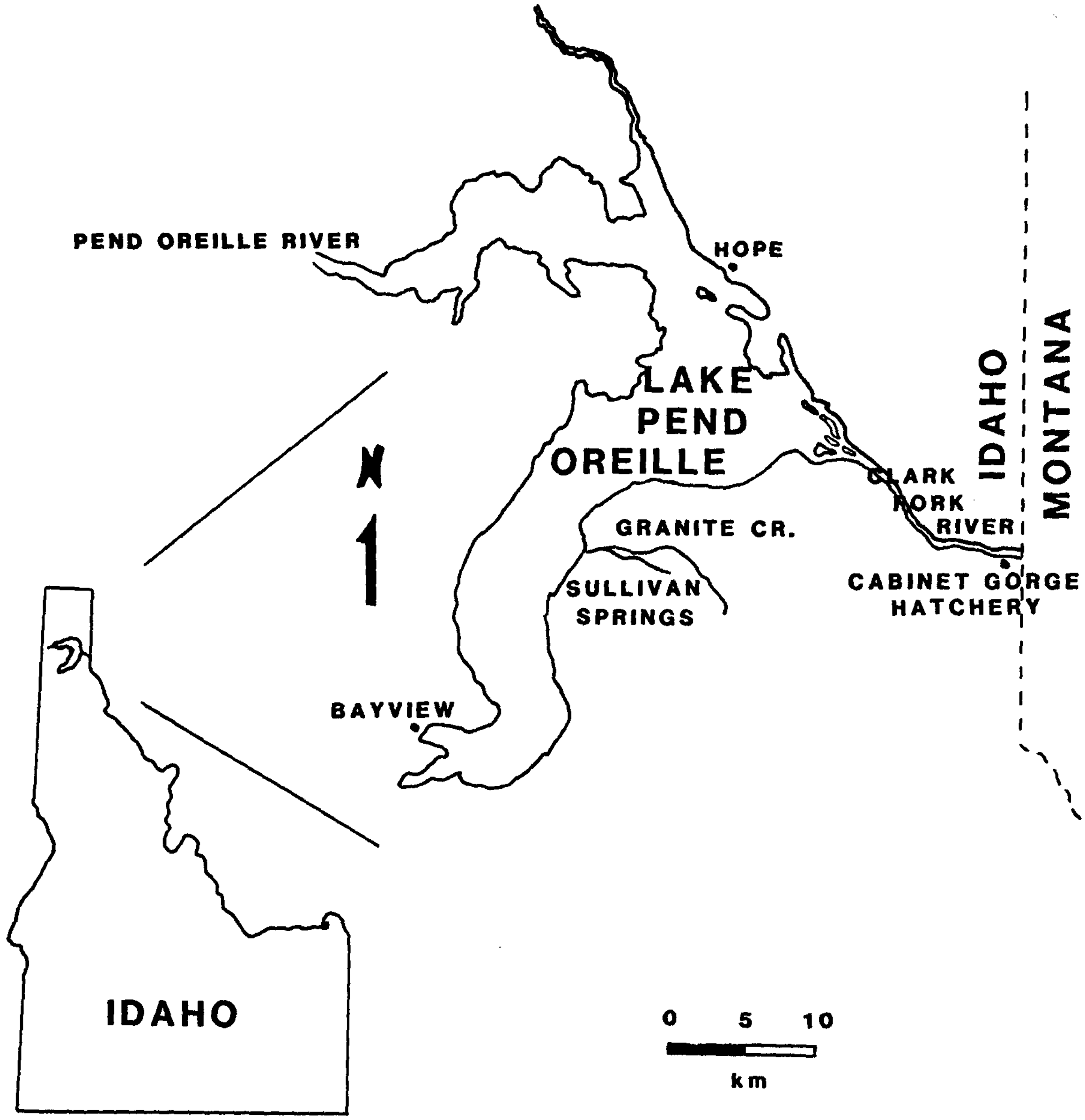

Figure 1. Map of Lake Pend Oreille, Idaho.

(Figure 2). The area of each section was calculated for the 91.5 m contour; however, Section 6 (the northern end) was calculated from the 36.6 m contour because of shallower water. The 91.5 m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). Six transects were systematically selected within each section, and one haul (sample) was made along each transect. Total sample size in 1989 was 36 hauls.

Fish numbers/transect (haul) were divided by transect volume and the age-specific and total number of kokanee for each stratum and lake total were calculated using standard expansion formulae for stratified sampling designs (Scheaffer et al. 1979). Kokanee population estimates (total and by section) were divided by respective lake surface areas to calculate kokanee densities (number/hectare) for each age-class. Confidence intervals (90%%) were calculated to compare estimates among age-classes, lake sections, and years.

Survival

Recruitment and survival of hatchery-reared and wild fry were determined from trawl catches during late August of marked or unmarked fry. Fry survival was estimated from potential egg deposition (PED) and release date (hatchery fry only) to late August abundance in Lake Pend Oreille. PED was calculated by multiplying average fecundity by estimated mature female kokanee abundance. Hatchery-reared fry were differentiated among release groups by a tetracycline mark or by analyzing daily growth increments on fry otoliths. Annual survival was estimated for age 1+ and older kokanee by comparing trawl-estimated abundance for each year-class between years. Relative distribution of kokanee age-classes was determined from abundance estimates for trawl catches within each section.

Fry Markinq

Tetracycline

Fry were marked with tetracycline during hatchery residence. Tetracycline (TM-100) was mixed with fish feed, at the rate of 5.5% of diet weight, and fed to kokanee fry for 10 d prior to their release into Lake Pend Oreille. All fry were marked and held inside the hatchery or under covered raceways because the mark degrades when exposed to ultraviolet (UV) light. Kokanee fry captured in the trawl during late August were examined for tetracycline marks with a longwave (3,600 angstrom) ultraviolet light. When exposed to ultraviolet light, a yellow sheen is observed around the mandibles, opercles, and bases of pelvic and pectoral fins. This mark is visible for several months after release (Bowles et al. 1989).

Section	Area (hectares)
1	3,166
2	3,220
3	3,739
4	4,036
5	3,373
6	5,011

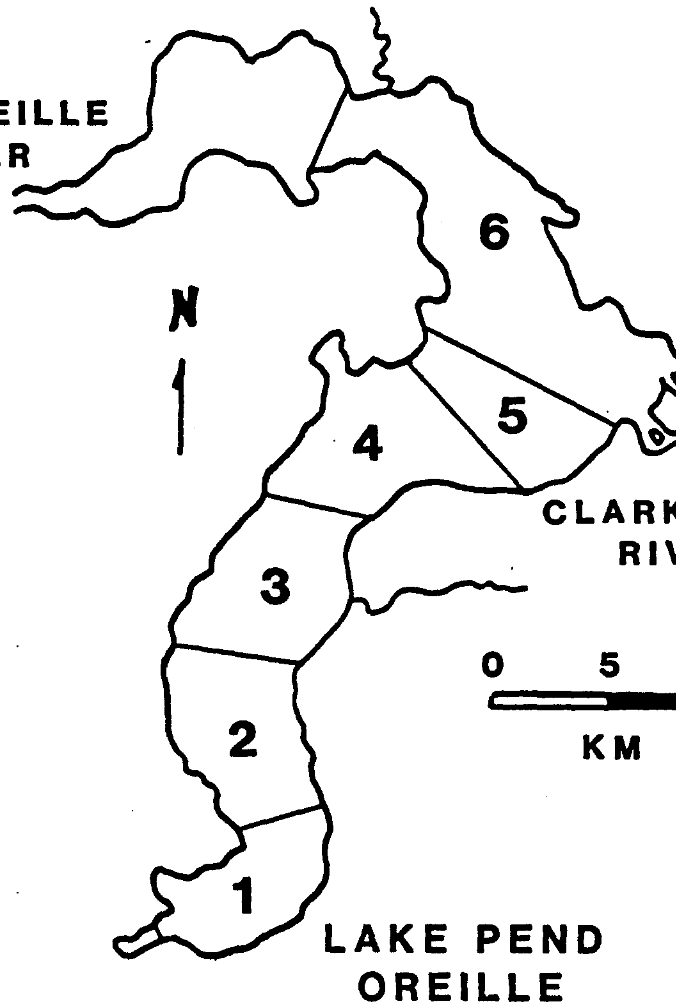

Figure 2. Stratified sampling sections and respective areas (hectares used during 1989 for trawling and kokanee abundance estimat on Lake Pend Oreille, Idaho.

Otolith Coding

Release date mark-Otoliths from kokanee reared at Cabinet Gorge Hatchery exhibit an obvious change in width of daily growth increments at the time of their release (Bowles et al. 1988, 1989). This mark was used to distinguish hatchery residence from lake residence. Kokanee released on different dates were identified by counting daily growth increments from the release mark to the otolith margin (trawl sampling date). Sagitta otoliths were excised from fry caught during trawling and embedded in a low viscosity medium (Spurr 1969). The proximal surface was polished (600 grit paper) and otolith microstructure observed (1,000 power) with an oil immersion compound microscope interfaced with a video camera and monitor.

Otoliths from age 1+ kokanee collected during autumn trawling were examined for a date-of-release mark similar to that described for kokanee fry. This mark was used to distinguish fish of hatchery vs. wild origin.

Fin Clip

A fin was clipped from selected groups of kokanee fry to help evaluate fry-to-adult return rates to spawning stations at Cabinet Gorge Hatchery and Sullivan Springs Creek. Possible clips included the adipose fin and left or right pelvic fins. Fry were clipped at least 1 week prior to release and averaged 49 mm total length (1,054 fry/kg). Fry were anesthetized (MS-222 at 40 mg/L water) prior to handling. Representative samples from each group were retained in the hatchery to evaluate fry mortality and fin regeneration.

Fry Release Strategies

Six fry release strategies were evaluated to optimize survival of fry in Lake Pend Oreille and adult returns to egg-take stations at Cabinet Gorge Hatchery and Sullivan Springs Creek. Table 1 summarizes location, date, size and number of fish released, and marks used to differentiate release groups.

Clark Fork River

Approximately 4.5 million fry were released in Clark Fork River to establish a spawning run to Cabinet Gorge Hatchery. All fry were imprinted with morpholine (5×10^{-5} mg/L in hatchery water) for 3 d prior to release. Morpholine was also added to hatchery water flowing from the fish ladder at Cabinet Gorge Hatchery into Clark Fork River for 3 d following each release. Two strategies were evaluated for fry released into Clark Fork River.

Table 1. Hatchery-reared kokanee fry released into Lake Pend Oreille, Idaho, during 1989.

Release strategy[a]	Release site	Release dates	Time	Number released (millions)	Mean size (mm)	Marks[a]
Clark Fork River						
Early summer	Cabinet Gorge Hatchery	6/21	dusk	3.513	46	Otolith code
Midsummer (barge)	Cabinet Gorge Hatchery (barged to Clark Fork River mouth)	7/17-19	day/dusk	0.984	49	Otolith code Tetracycline
			Subtotal	4.497		
Sullivan Springs	Sullivan Springs	7/11-13	day/night	3.538	51	Otolith code
			Subtotal	3.538		
Open Water						
Early summer	Northern Lake Pend Oreille	6/29	day	1.256	46	Otolith code Tetracycline
Midsummer	Southern Lake Pend Oreille	7/26	day	1.428	56	Otolith code
			Subtotal	2.684		
Shoreline	Southern Lake Pend Oreille	7/27-28	night	1.024	55	Otolith code Tetracycline
			Subtotal	1.024		
			Total	11.743	50	

[a] Refer to the Methods section for detailed descriptions of release strategies and marks.

Early season release-Approximately 3.5 million fry were released through the Cabinet Gorge Hatchery fish ladder into Clark Fork River on June 21, 1989. This release was scheduled to coincide with high nighttime river flows resulting from spring snowmelt. This early season release allowed WWP to provide an average hourly discharge of 1,024 m^3/s (36,203 ft^3/s) flows from Cabinet Gorge Dam for 2.5 nights following the fry release (Figure 3). Nighttime electrofishing (DC) near the mouth of Clark Fork River (22 km from hatchery) was used to estimate fry emigration rate and potential fry mortality from predation. Fry emigration rate was estimated by comparing catch-per-unit-effort of fry from three stations in the Clark Fork River delta sampled for two nights following the fry release. Stomachs were examined from potential predators caught during electrofishing to determine relative degree of predation throughout the night. The otolith date-of-release mark was used to distinguish fry during autumn trawling in Lake Pend Oreille. Approximately 41,000 fry were fin-clipped (left pelvic) to provide an estimate of the fry-to-adult return rate for spawners migrating to the hatchery in 1992 and 1993.

Mid-summer release-During July 17-19, 1989, approximately 1 million fry were barged down Clark Fork River and released into Lake Pend Oreille near the river mouth. This strategy evaluated the feasibility of transporting fry down Clark Fork River during mid-summer when nighttime flows are low (>1,000 m^3/s) but availability of forage (cladoceran zooplankton) in Lake Pend Oreille is high. Transportation was necessary because fry emigration success to Lake Pend Oreille during low (>570 m^3/s) nighttime flows is poor (Bowles et al. 1987, 1988). Fry were barged to allow them to imprint on Clark Fork River water, which may enhance adult returns to Cabinet Gorge Hatchery for spawning. The 8.5 m pontoon barge held 8.8 m^3 water in two circular tanks, which were aerated and plumbed to provide a constant flow of river water to fry. The barge transported a maximum of 150,000 49-mm fry (17 kg/m^3 loading density) each 4-h trip from Cabinet Gorge Hatchery to Lake Pend Oreille (22 km). Marks used to distinguish this release group during trawling included tetracycline and the otolith date-of-release mark. Approximately 40,000 fry were also fin-clipped (right pelvic) to help evaluate adult returns for *spawning* in 1992 and 1993.

Sullivan Springs

Approximately 3.5 million fry were transported by truck from Cabinet Gorge Hatchery to Sullivan Springs Creek during July 11-13, 1989. The fry were transported at a density of 55 to 59 kg/m in 10.0°C water and released into 7.2°C creek water. The purpose of this release was to insure continued adult returns to the egg-take station on this spring-fed tributary to Lake Pend Oreille. The otolith date-of-release mark was used to distinguish fry during autumn trawling in Lake Pend Oreille. Approximately 40,000 fry were also fin-clipped (adipose) to evaluate adult returns for spawning in 1992 and 1993.

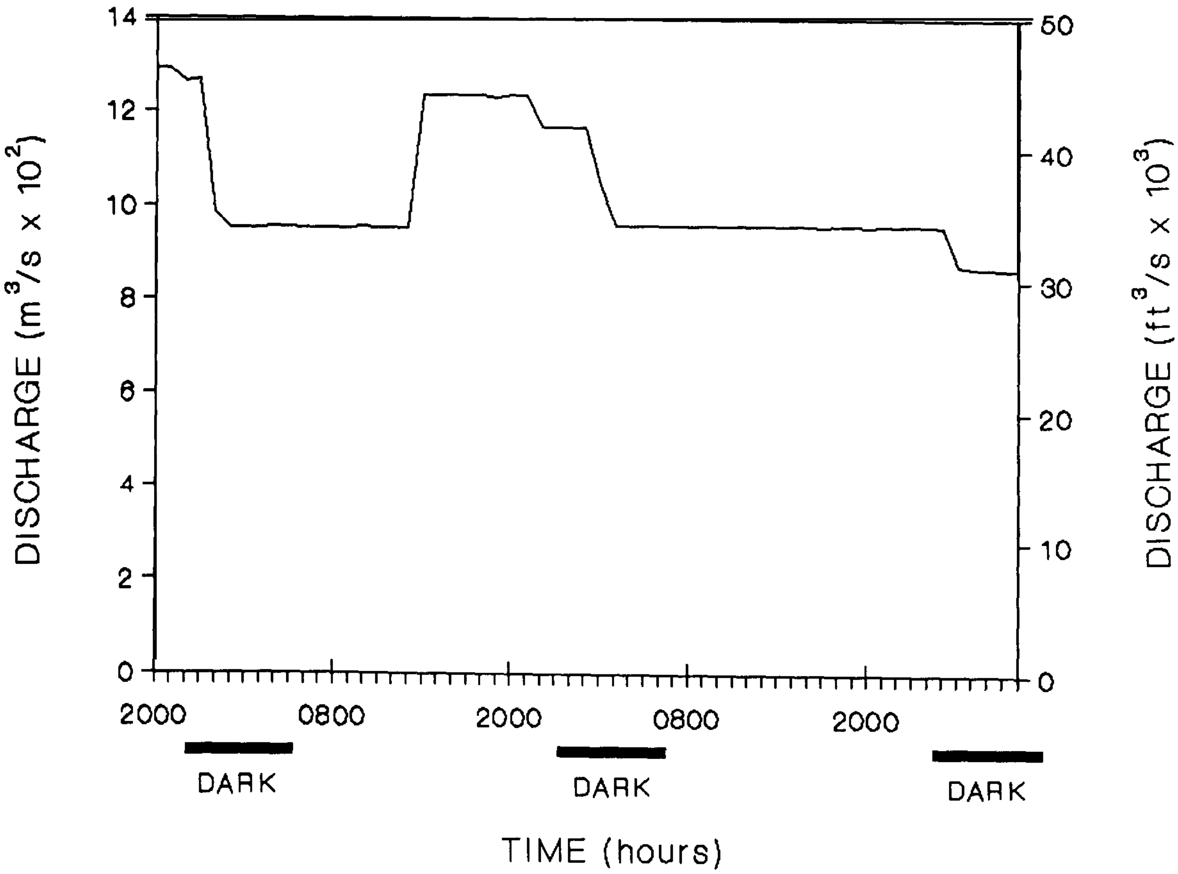

Figure 3. Discharge from Cabinet Gorge Dam into Clark Fork River during three nights (June 15-17, 1989) following the fry release (at 2100 hours the first night) from Cabinet Gorge Hatchery.

Open-Water

Approximately 2.7 million fry were released into Lake Pend Oreille to evaluate survival of open-water releases made before and after thermal stratification of Lake Pend Oreille.

Early season release-Approximately 1.3 million fry were released June 29, 1989 in northern Lake Pend Oreille, 3 km southwest of Hope, Idaho (Figure 1). Kokanee were trucked at a density of 47 to 50 kg/m^3 in 9.0°C water from Cabinet Gorge Hatchery to the town of Hope. Each truck was transported to the release site on a 200-ton barge towed by a 300-hp tugboat. Fry were released from approximately 14.0°C water after acclimation for 90 min to lake surface water of 17.5°C. Marks used to distinguish this release group during trawling included tetracycline and the otolith date-of-release mark.

Mid-summer release-Approximately 1.4 million fry were released July 26, 1989 in southern Lake Pend Oreille, 2 km east of Bayview, Idaho (Figure 1). Kokanee were trucked at a density of 60 to 74 kg/m^3 in 11.6°C water from Cabinet Gorge Hatchery to the town of Bayview. Each truck was transported to the release site with a 200-ton work barge and tug supplied and operated by the U.S. Department of Navy, Naval Acoustic Research Detachment. Fish were released from approximately 16.5°C water after acclimation for 60 min to lake surface water of 20.0°C. The otolith date-of-release mark was used to distinguish fry during autumn trawling in Lake Pend Oreille.

South Shoreline

Approximately 1 million fry were released July 27-28, 1989 in southern Lake Pend Oreille at Farragut State Park public boat launch, 2 km southeast of Bayview, Idaho (Figure 1). Kokanee were trucked at a density of 50 to 74 kg/m^3 in 11.6°C water from Cabinet Gorge Hatchery to Farragut State Park. They were acclimated for 105 min to lake surface water of 22.0°C and released. This release strategy evaluated the survival of kokanee from a less expensive release along shoreline. Marks used to distinguish this release group during trawling included tetracycline and the otolith date-of-release mark.

Egg-Take

Since 1974, IDFG has maintained a permanent weir at the mouth of Sullivan Springs Creek (tributary to Granite Creek), a major kokanee spawning tributary to Lake Pend Oreille (Figure 1). This egg-take station has provided kokanee eggs for Lake Pend Oreille, as well as enhancement activities for other lakes. Additional eggs were collected from kokanee spawners at the Cabinet Gorge Hatchery fish ladder on Clark Fork River.

Naturally Spawning Kokanee

Adult kokanee were enumerated along lakeshore and tributary stream spawning areas to provide an index of naturally spawning kokanee abundance. Counts were made by walking each area once during the first week of December, the estimated peak of spawning activity. Only predetermined portions of lakeshore spawning areas were surveyed, whereas entire spawning areas were censused in tributary streams. Trestle Creek was also censused in September to determine use by early run kokanee spawners.

Age and Length at Maturity

Total length was measured and otoliths extracted from mature kokanee collected during the late fall spawning season for spawner age and length distributions. Spawners were collected from Spring Creek and the weir at Sullivan Springs Creek. Age of maturity was also estimated for kokanee collected during August trawling.

Mysid Shrimp

Mysis were sampled at night during the dark moon phase the first week of June. Five samples were collected randomly in the southern, central, and northern portions of Lake Pend Oreille (Figure 4). Samples were collected with a Miller high-speed sampler equipped with a General Oceanics flow meter and a 130 micron-plankton net and bucket. Stepped oblique tows were made from 46 m to the surface, sampling for 10 s at each 3 m interval. The sampler was towed approximately 1.5 m/s and raised 0.5 m/s with an electric winch. *Mysis* from each sample were counted and differentiated by age-class (juvenile or adult). Density estimates were based on volume of water filtered, and comparisons made between age-classes and among lake sections and years.

Size and sex data were recorded for *Mysis* from two samples/lake section. Mysids were measured from the tip of the rostrum to the tip of the telson, excluding setae, and classified into five categories according to sex characteristics: juveniles, immature males and females, and mature males and females (Gregg 1976; Pennak 1978).

Zooplankton

The zooplankton community was sampled in the southern, central, northern, and Clark Fork River delta portions of Lake Pend Oreille (Figure 4). Five random samples were collected monthly from each section from May through October in the

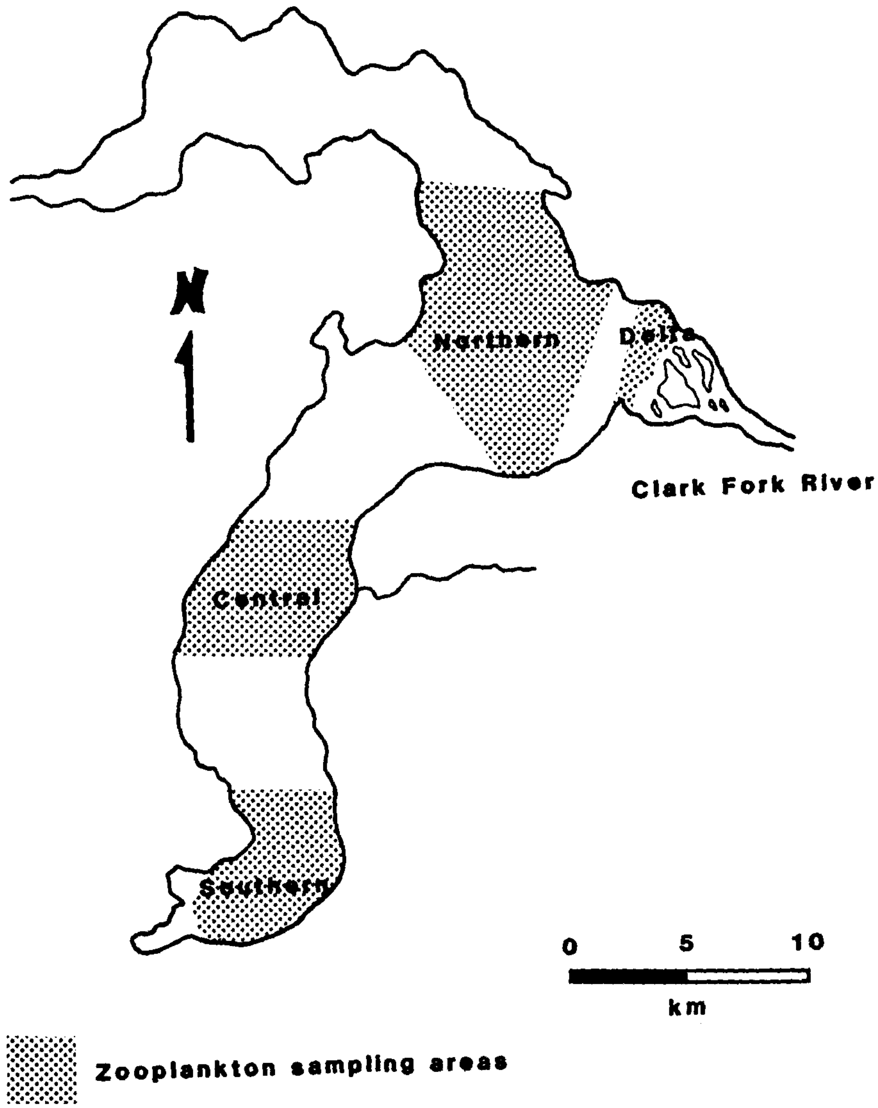

Figure 4. Zooplankton sampling areas on Lake Pend Oreille, Idaho.

main body of the lake and from June through September in the delta section. Samples in the main body of the lake were collected with a 0.5 m diameter ring plankton sampler, calibrated by a General Oceanics flow meter and equipped with a 130 micron net and bucket. Vertical hauls from 27.4 m depths to the surface were made by raising the sampler approximately 0.5 m/s with an electric winch. Samples from the shallower delta section were collected with a Miller high-speed plankton sampler equipped with a flow meter and 130 micron net and bucket. In the delta, the entire water column was sampled with oblique tows stepped at 1.5 m or greater intervals. The sampler was towed at 1.5 m/s for a 90 s/sample. Zooplankters were enumerated by genus using standard dilution and subsampling methods (Edmondson and Winberg 1971). Enumeration data were standardized by volume of water filtered to determine zooplankton densities. Up to 30 organisms/genus/sample were measured by projecting their image on a calibrated screen. Mean lengths were calculated for each month and lake section. Analysis of variance, utilizing a stratified random sampling scheme, was used to compare zooplankton densities and lengths, both spatially and temporally.

Water Temperature and Transparency

Thermal stratification of Lake Pend Oreille was monitored by measuring water temperature monthly from May through November at one site in the southern section of the lake. Instantaneous temperatures were measured with a probe from the surface to 50 m depths at 1 m intervals for the first 5 in, and at 5 m intervals thereafter. When a more dramatic change in temperature was noticed within a 5m sample, temperatures were measured at 1 m intervals to better define the thermocline. Water transparencies were monitored temporally and spatially. A Secchi disk reading was taken in the southern, central, and northern sections of Lake Pend Oreille each month from May through October.

RESULTS

Kokanee Abundance, Distribution, and Biomass

Estimated total kokanee abundance during late August, 1989, was 7.71 million fish (Figure 5). Contribution of individual year-classes was 4.48 million for the 1988 year-class (age 0+), 1.17 million for the 1987 year-class (age 1+), 1.20 million for the 1986 year-class (age 2+), 0.45 million for the 1985 year-class (age 3+), 0.37 million for the 1984 year-class (age 4+), and 0.04 million for the 1983 year-class (age 5+).

Estimated average kokanee density for the entire lake (all age-classes combined) was 341 kokanee/hectare (Figure 6; Appendix A). Densities ranged from a high of 499 kokanee/hectare in Section 1 to a low of 211 kokanee/hectare in Section 5. Age 0+ wild kokanee densities were highest in southern and central sections of Lake Pend Oreille, whereas hatchery fry densities were highest in central sections of the lake. Densities of age 1+ kokanee were highest in the

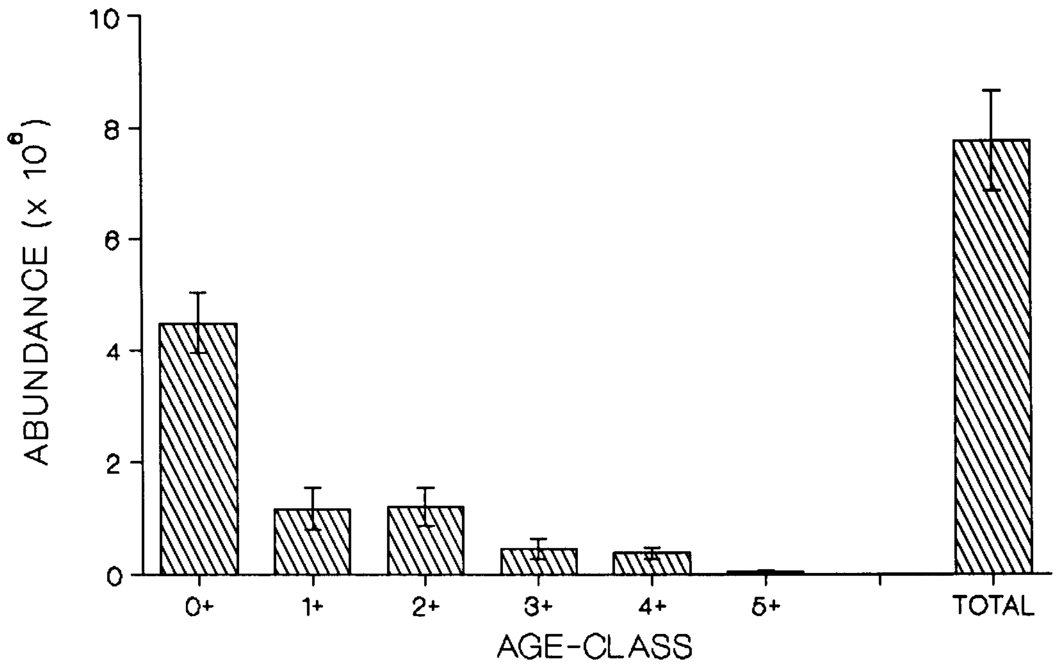

Figure 5. Estimated kokanee abundance, with 90% confidence intervals, during late August, 1989, Lake Pend Oreille, Idaho.

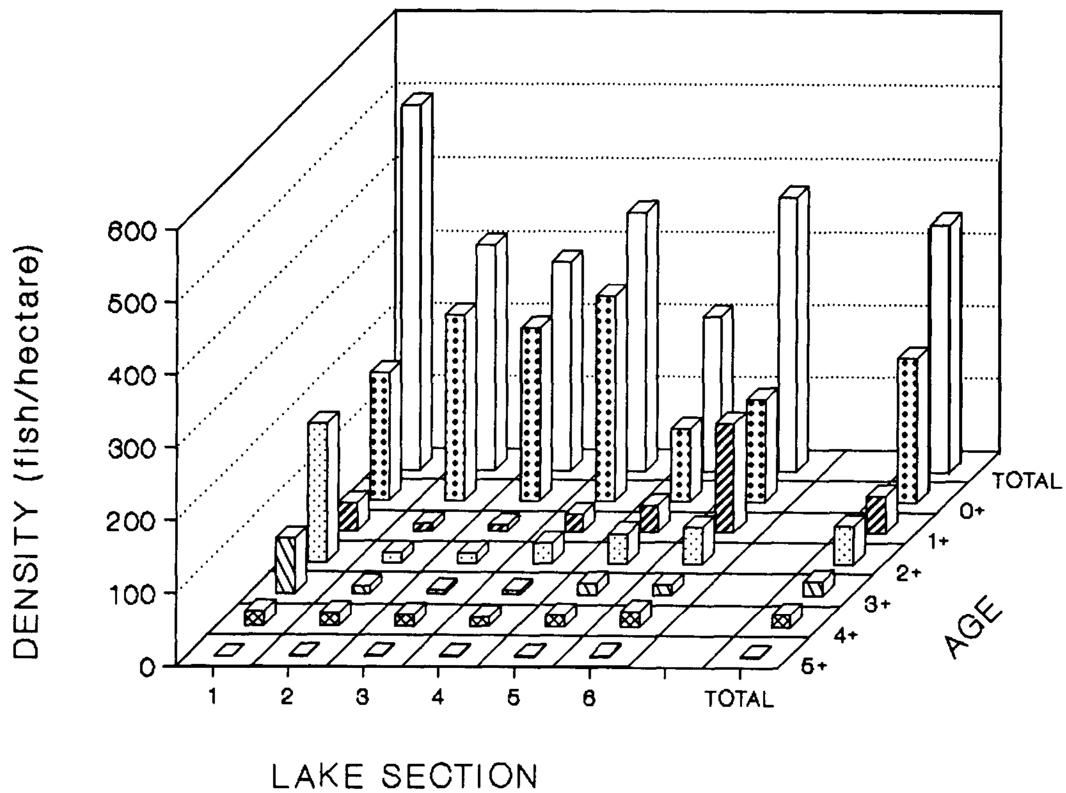

Figure 6. Kokanee density in Lake Pend Oreille, Idaho, by age-class and lake section during late August, 1989.

northern section of Lake Pend Oreille and lowest in southern and central sections. Densities of age 2+ and age 3+ kokanee were highest in the southern section of Lake Pend Oreille and lowest in central sections. Densities of age 4+ kokanee were equally abundant in all sections of the lake, whereas age 5+ kokanee were highest in the northern section and lowest in the southern section of Lake Pend Oreille.

Estimated kokanee biomass in Lake Pend Oreille during late August was 219,961 kg (9.71 kg/hectare) (Table 2). Biomass of hatchery-reared kokanee fry was 3,144 kg (0.14 kg/hectare), 80% of total fry biomass in the lake. Estimated biomass of age 1+ and older kokanee was 216,057 (9.54 kg/hectare). Length frequencies and mean lengths and weights of kokanee caught in the trawl are shown in Figure 7 and Table 2.

Spawning Escapement

An estimated 469,766 mature kokanee comprised the Lake Pend Oreille spawning population in 1989. The 1989 spawning run to Sullivan Springs Creek was approximately 79,450 kokanee (17% of the total escapement) and extended from early November, 1989 to early January, 1990. The estimated return of hatchery-reared fry as adults in 1989 was 1.7%. One-time late spawning kokanee counts (December) in other tributaries ranged from 2,400 spawners in Spring Creek to 0 spawners observed in Johnson, Twin, Trestle, and Garfield Creeks (Appendix B). Counts of lakeshore spawning kokanee ranged from 875 on southern beaches to only 2 kokanee spawners counted on northern lakeshore areas. A count of 466 early-run kokanee spawners was made in Trestle Creek during September.

Age and Length at Maturity

Age composition of mature kokanee captured during trawling in 1989 was 12% age 3+, 78% age 4+, and 10% age 5+ (N=49). An estimated 14% of age 3+ kokanee were mature and consisted of 29% males and 71% females. Approximately 98% of age 4+ kokanee were mature and consisted of 40% males and 60% females, while 100% of age 5+ kokanee were mature and consisted of 65% males and 35% females. Age composition of kokanee spawned during 1988 from Sullivan Springs Creek was 80% age 4+ and 20% age 3+ (N=55). Age composition for spawners collected during 1989 will be reported in the Annual Report for fiscal year 1990.

Mean lengths of kokanee spawners did not vary significantly ($P>0.05$) among spawning sites during 1989. Mean lengths of male kokanee from Sullivan Springs and Spring Creeks were 277 ± 4 mm (N=44) and 284 ± 11 mm (N=11), respectively. Mean lengths of female kokanee were 266 ± 3 mm (N=36) from Sullivan Springs Creek and 274 ± 14 mm (N=6) from Spring Creek.

Table 2. Mean length, weight, and biomass of kokanee caught while trawling during late August, 1989, Lake Pend Oreille, Idaho.

Age class	Mean length (mm)	Mean weight (g)	Biomass kg	Biomass kg/hectare
Age 0+				
Hatchery	55	1.40	3,144	0.14
Wild	34	0.34	760	0.03
Combined	45	0.87	3,904	0.17
Age 1+	154	27	31,254	1.38
Age 2+	199	65	77,546	3.42
Age 3+	224	97	43,482	1.92
Age 4+	260	151	56,342	2.49
Age 5+	276	176	7,452	0.33
All ages	-	-	219,961	9.71

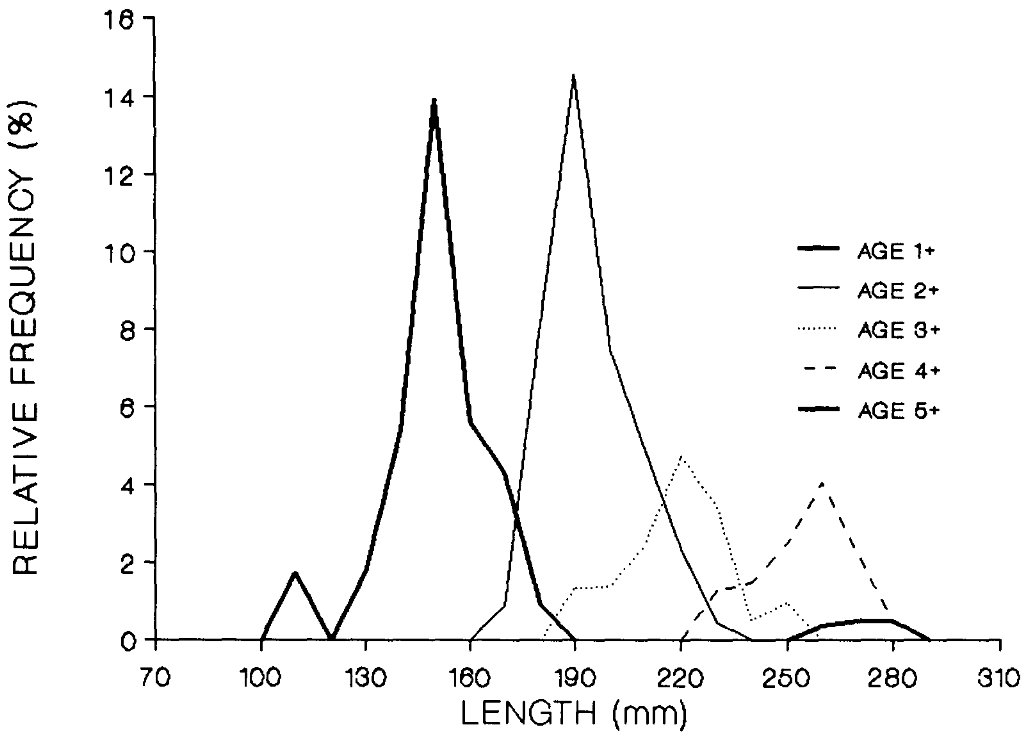

Figure 7. Length frequency of kokanee, by age-class, in Lake Pend Oreille, Idaho, during late August, 1989.

Potential Egg Deposition

Estimated total potential egg deposition for 1989 was 117.6 million, with 107.1 million eggs attributed to natural spawning and a potential of 10.5 million eggs available from artificially spawned kokanee at Sullivan Springs. Estimated abundance of mature female kokanee was 276,010 fish determined from August trawling. Approximately 24,700 female kokanee were spawned at the Sullivan Springs trap, which left an estimated 251,310 female kokanee to spawn naturally throughout Lake Pend Oreille and its tributaries. Fecundity averaged 426 ± 26 (N=46, alpha=0.05) viable eggs/female.

Egg-Take

Egg-take from the 1989 year-class for Lake Pend Oreille totaled 9.58 million. Kokanee spawned at Sullivan Springs provided 9.37 million eggs (388 ± 28 eggs/female; N=46, alpha=0.05), which represents a 91% spawning efficiency. An additional 0.21 million eggs were taken at Cabinet Gorge Hatchery from kokanee migrating up Clark Fork River.

Fry Emigration and Predation

Relative catches of hatchery-reared kokanee fry at the mouth of Clark Fork River indicated that 99% of fry successfully emigrating to Lake Pend Oreille completed the journey the first night following their release at Cabinet Gorge Hatchery. Kokanee fry were first observed at the mouth 3 h following their release.

Predation on kokanee fry during emigration through the lower Clark Fork River and delta was minimal. Fourteen kokanee fry were observed in 14% of the squawfish *Ptychocheilus oreqonensis* stomachs (N=14). No kokanee were observed in stomachs of largescale suckers *Catostomus macrocheilus* (N=18), mountain whitefish (N=9), yellow perch *Perca flavescens* (N=7), and peamouth *Mylocheilus caurinus* (N=3) collected electrofishing during two nights following the fry release at Cabinet Gorge Hatchery. All squawfish captured were immature and less than 330 mm total length. Three marked Kamloops (Gerrard) rainbow trout were captured.

Survival and Recruitment

Estimated kokanee fry survival (hatchery and wild fish combined) from potential egg deposition to late August trawl sampling was 3.8% for the 1988 year-class. Survival estimates for hatchery and wild fry were 14.0% and 2.2%, respectively. A survival rate of 19 + 3% was estimated for the 1988 year-class hatchery-reared fry from time of release late June through July to fall sampling in late August.

Fry survival from release to fall trawling was 18 ± 4% for the early season release in Clark Fork River, 16 ± 5% for the mid-summer release (barged) in Clark Fork River, 21 ± 3% for fry released in Sullivan Springs Creek, 5 ± 2% for the early season open-water release (north), 25 ± 5% for the mid-summer open-water release (south), and 27 ± 9% for the mid-summer shoreline release (south) (Figure 8). Fry survival associated with the early season open-water release was significantly lower ($P<0.10$) than any other release. Pairwise comparisons between other release strategies did not show significant differences ($P>0.10$).

Hatchery fry provided an estimated 50% of the total kokanee fry recruitment in 1989. Fry released into Sullivan Springs and Clark Fork River made up 17% and 18%, respectively, of total fry recruitment in Lake Pend Oreille (33% and 35% of hatchery fry recruitment). Open-water releases contributed 9% to total fry recruitment (19% of hatchery fry recruitment). The mid-summer shoreline release contributed 6% to total fry recruitment (12% of hatchery fry recruitment). Although dispersal of hatchery-reared fry throughout the lake was evident following 1 to 2.25 months of lake residence, abundance remained highest in lake sections near release sites (Figure 9).

Estimated annual survival (late summer 1988 to late summer 1989 for wild and hatchery fish combined) was 16% for the 1987 year-class (age 1+), 72% for the 1986 year-class (age 2+), 88% for the 1985 year-class (age 3+), 97% for the 1984 year-class (age 4+), and 12% for the 1983 year-class (age 5+).

Fry Marking

Analysis of daily growth rings on kokanee fry otoliths indicated an obvious mark at the time of release, which separated hatchery residence from lake residence. Mean width of daily growth increments was approximately two times larger during hatchery residence than lake residence. Approximately 69% of counts (N=146) from the date-of-release mark to the otolith margin fell within the expected number of days from the releases to fall sampling. Over 98% of counts were within 2 d of the expected dates.

Date-of-release marks similar to those observed on kokanee fry were discernable on age 1+ kokanee otoliths. Approximately 42% of the age 1+ kokanee otoliths analyzed (N=19) were of hatchery origin, as indicated by a date-of-release mark.

Mysid Shrimp

Density of _Mysis_ in Lake Pend Oreille during early June, 1989 averaged 0.041 organisms/L (Figure 10). This estimate was not significantly different ($0.435<P<0.767$) than estimated density for 1988 (0.047 organisms/L) or 1986

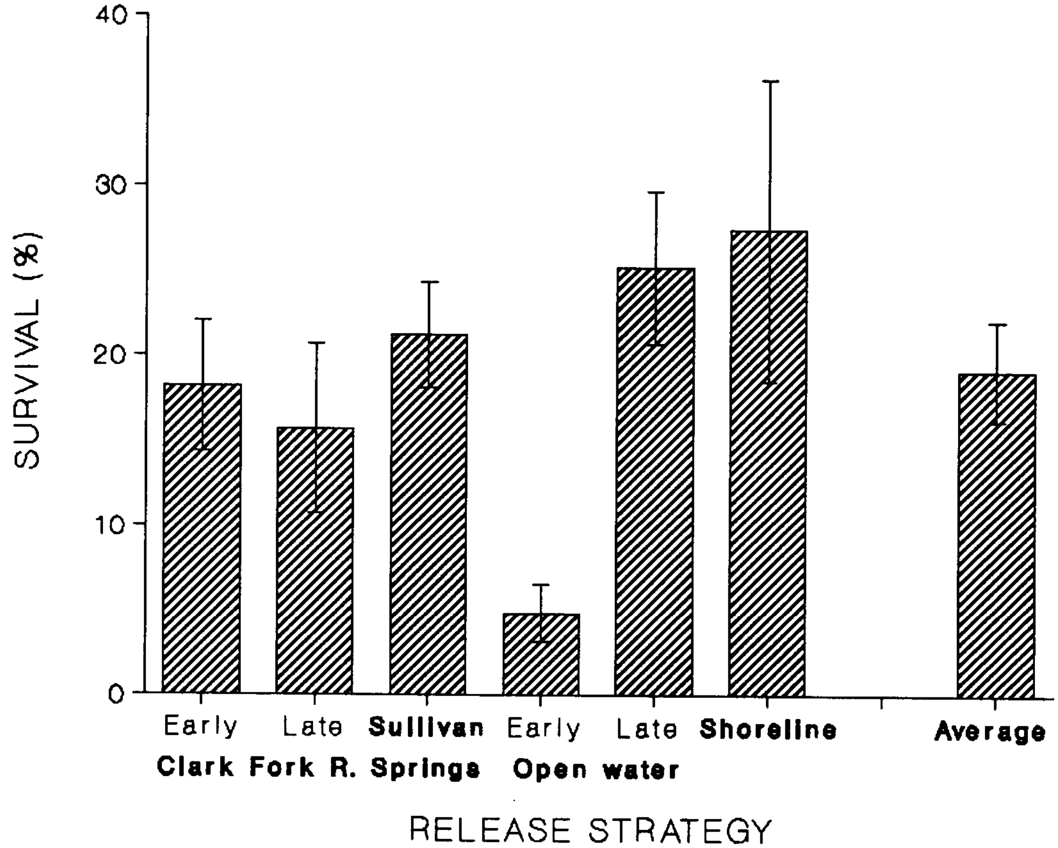

Figure 8. Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among six release strategies evaluated in 1989. A 90% error bound is depicted for each estimate.

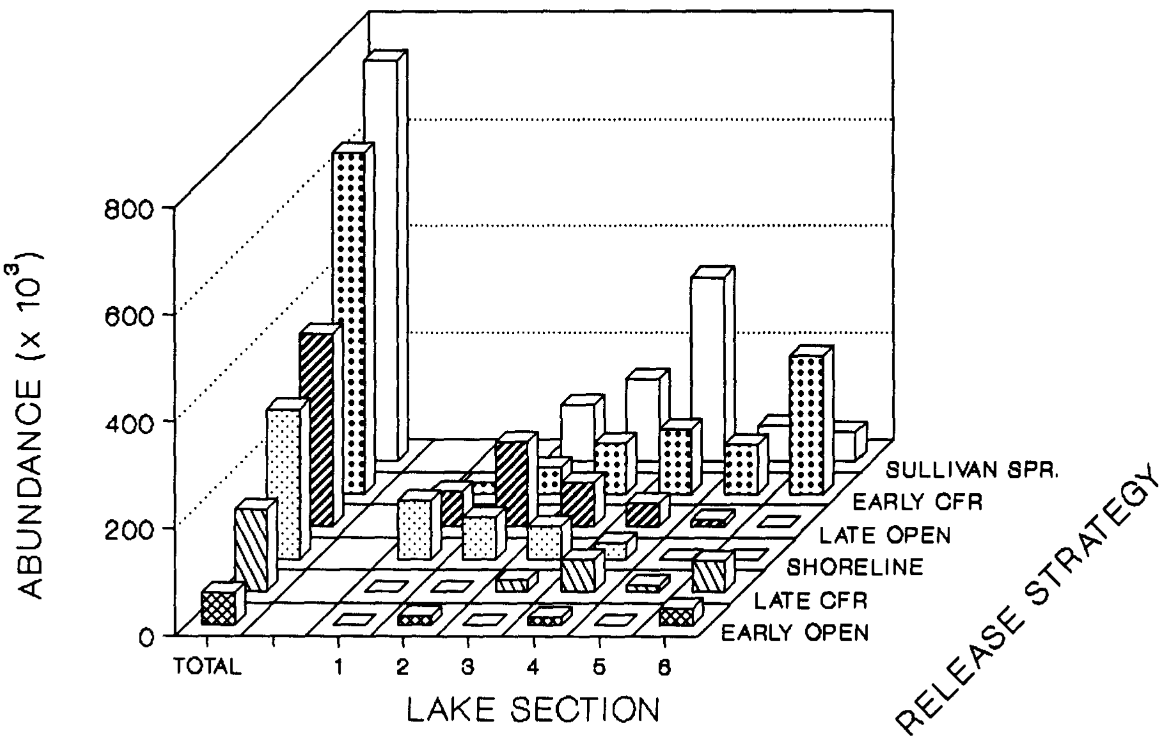

Figure 9. Abundance and distribution of hatchery-reared kokanee fry during late August, 1989, compared among six release strategies into Lake Pend Oreille, Idaho.

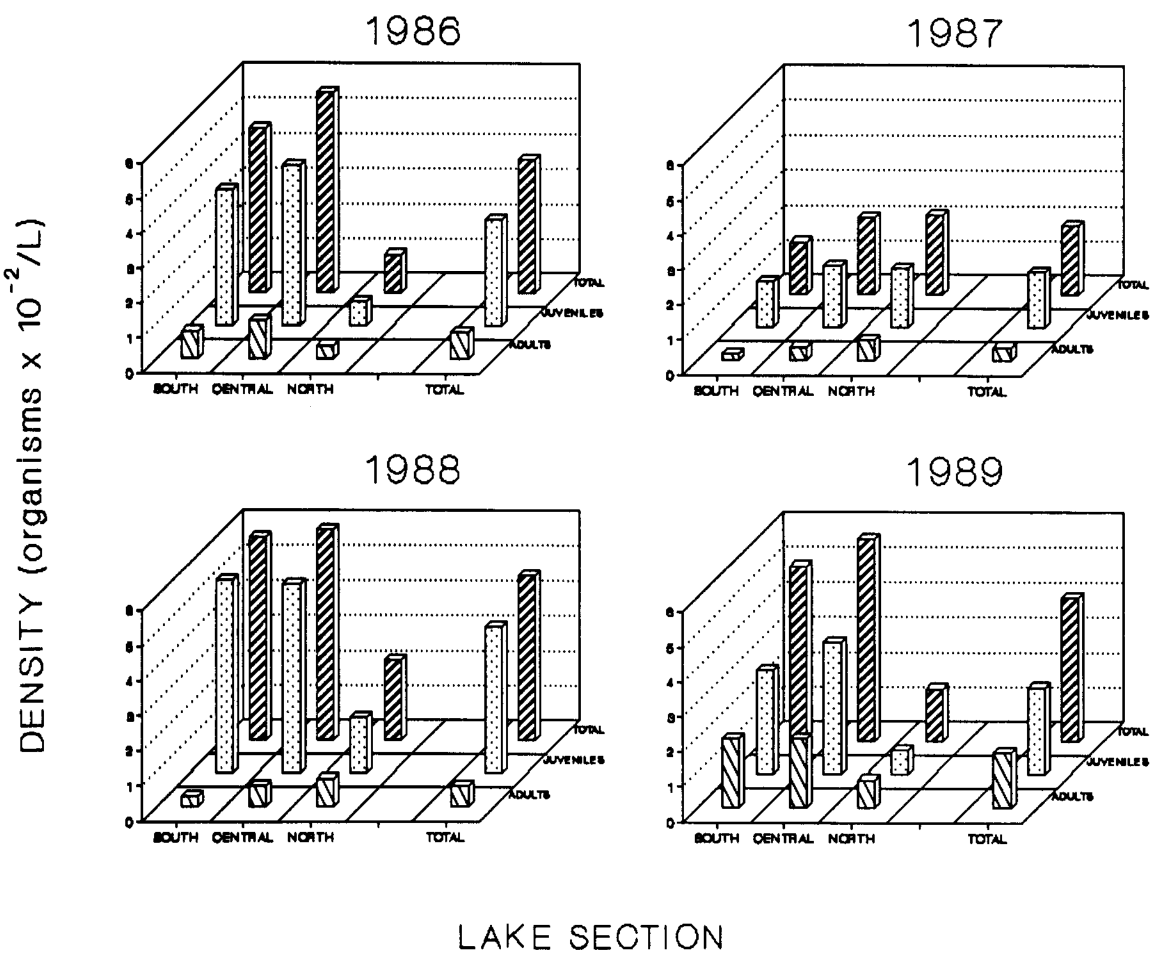

Figure 10. Mean adult, juvenile, and total densities of *Mysis* in Lake Pend Oreille, Idaho, sampled during June, 1986 through 1989.

(0.039 organisms/L), but was significantly higher (P=0.011) than the 1987 estimate (0.020 organisms/L). Total densities during 1986-1989 were similar (P=0.257) between southern and central lake sections and significantly lower (P=0.000) in the northern section.

Juveniles comprised 61% of total Mysis abundance in Lake Pend Oreille during early June, 1989, with an average density of 0.025 organisms/L (Figure 10). Estimated juvenile density in 1989 was not significantly different (0.201(P<0.396) than estimated density for 1987 (0.016 organisms/L) or 1986 (0.031 organisms/L), but was significantly lower (P=0.026) than the 1988 estimate (0.042 organisms/L). Juvenile densities during 1986-1989 were similar (P=0.377) between southern and central lake sections and significantly lower (P=0.000) in the northern section.

Adult mysids comprised 39% of total Mysis abundance during early June, 1989 (Figure 10). Adult density averaged 0.016 organisms/L and was significantly higher (P=0.000) than the estimated density for 1986 (0.008 organisms/L), 1987 (0.004 organisms/L), and 1988 (0.006 organisms/L). Adult densities in 1989 did not vary significantly (P=0.189) among northern, central, or southern sections of Lake Pend Oreille.

The length frequency of Mysis in Lake Pend Oreille during early June, 1989, suggested the contribution of three brood years, which ranged in length between 3 mm and 20 mm (Figure 11). Juvenile mysids made up the 1989 brood year and ranged in length between 3 mm and 10 mm. The 1988 brood year represented by immature mysids consisted of 54% males and 46% females, whereas only mature females were observed from the 1987 brood year.

Zooplankton Community

Generic composition of zooplankton in Lake Pend Oreille from May through October 1989 included Cyclops, Diaptomus, Epischura, Bosmina, Daphnia, and Diaphanosoma. Copepod densities were higher than cladoceran densities throughout the sampling period (Figure 12). Cladoceran production was highest during July and August, at approximately 16% and 22% of copepod production, respectively. Total zooplankton density ranged from approximately 9 organisms/L in May to approximately 38 organisms/L in July (Figure 13). The copepods Cyclops and Diaptomus were the most abundant zooplankters, with combined densities ranging from approximately 9 organisms/L in May to approximately 33 organisms/L in July. The average density of Cyclops (11.089 organisms/L) was significantly lower (P<0.10) in 1989 than 1988 (13.226 organisms/L), whereas the average density of Diaptomus (7.445 organisms/L) was not significantly different (P=0.985) from 1988 (7.455 organisms/L) (Figures 13 and 14, Appendix C). Epischura was the least abundant zooplankter during 1989, with an estimated density of 0.015 organisms/L. In general, cladocerans were not common in samples taken during 1989 until July, which is similar to 1985, 1986, and 1988, but one month behind cladoceran production in 1987. Bosmina density in 1989 (0.995 organisms/L) was significantly higher (P<0.10) than the previous four years, and peaked in July at 5.1 organisms/L. This estimate is 340% higher than the previous high of 1.5

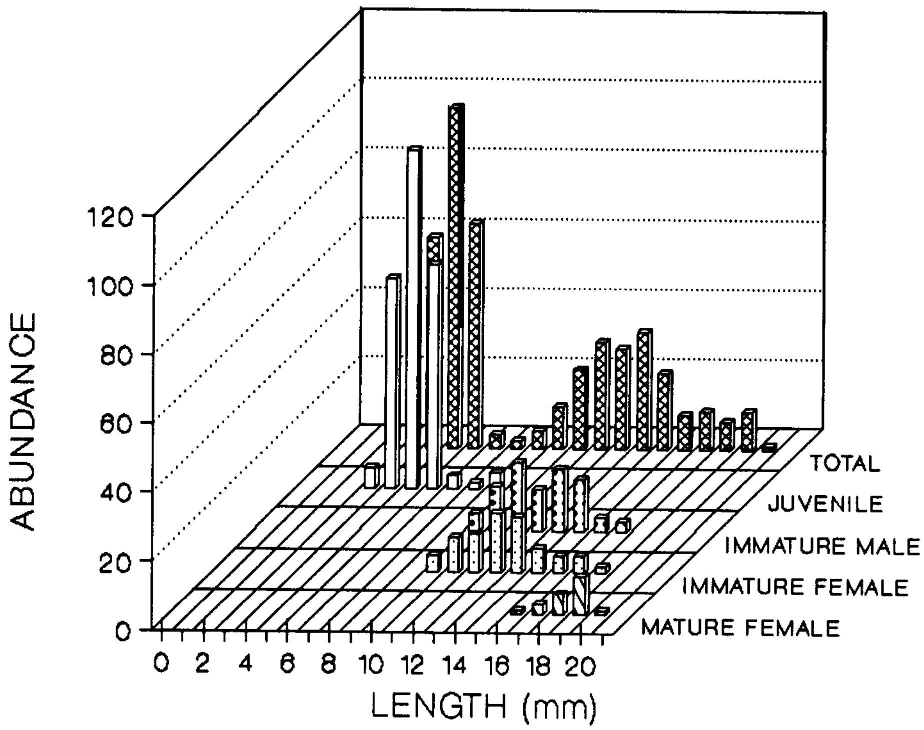

Figure 11. Lenth-frequency of Mysis, by size and sex, in Lake Pend Oreille, Idaho, during early June, 1989.

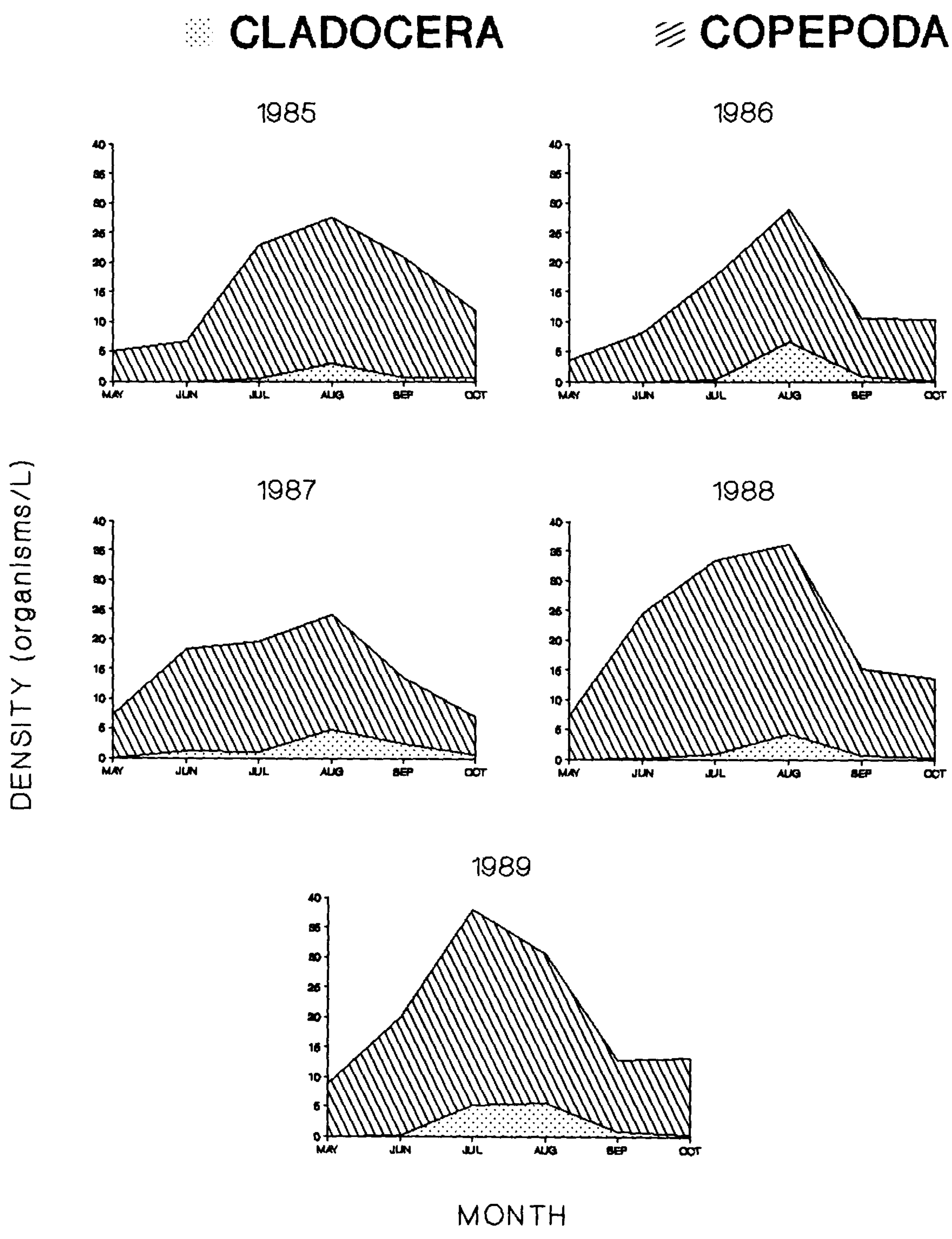

Figure 12. Temperal distribution of Copepoda and Cladocera zooplankton in Lake Pend Oreille, Idaho, May through October, 1985 to 1989.

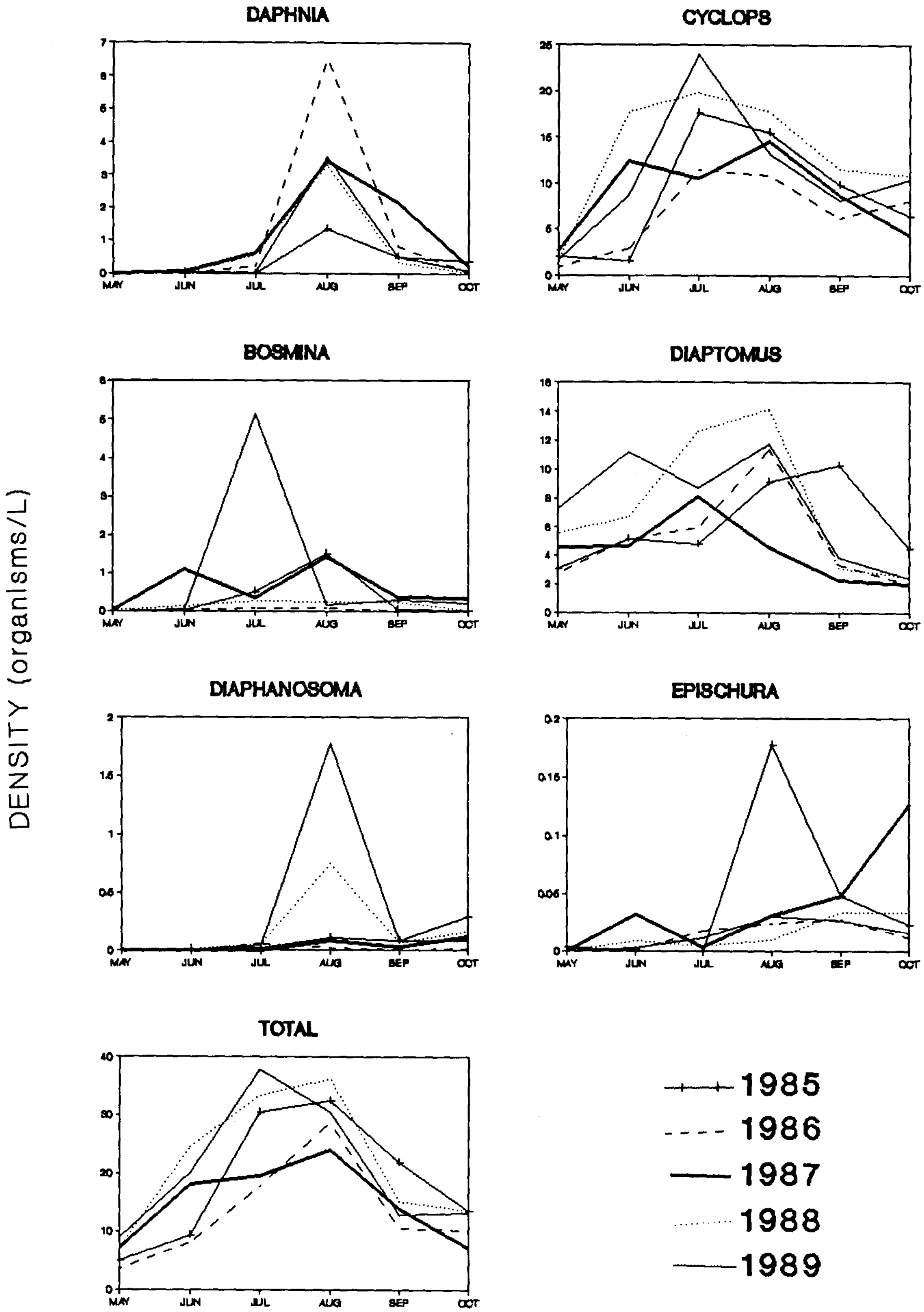

Figure 13. Temperal distribution of mean zooplankton densities in Lake Pend Oreille, Idaho, May through October, 1985 through 1989.

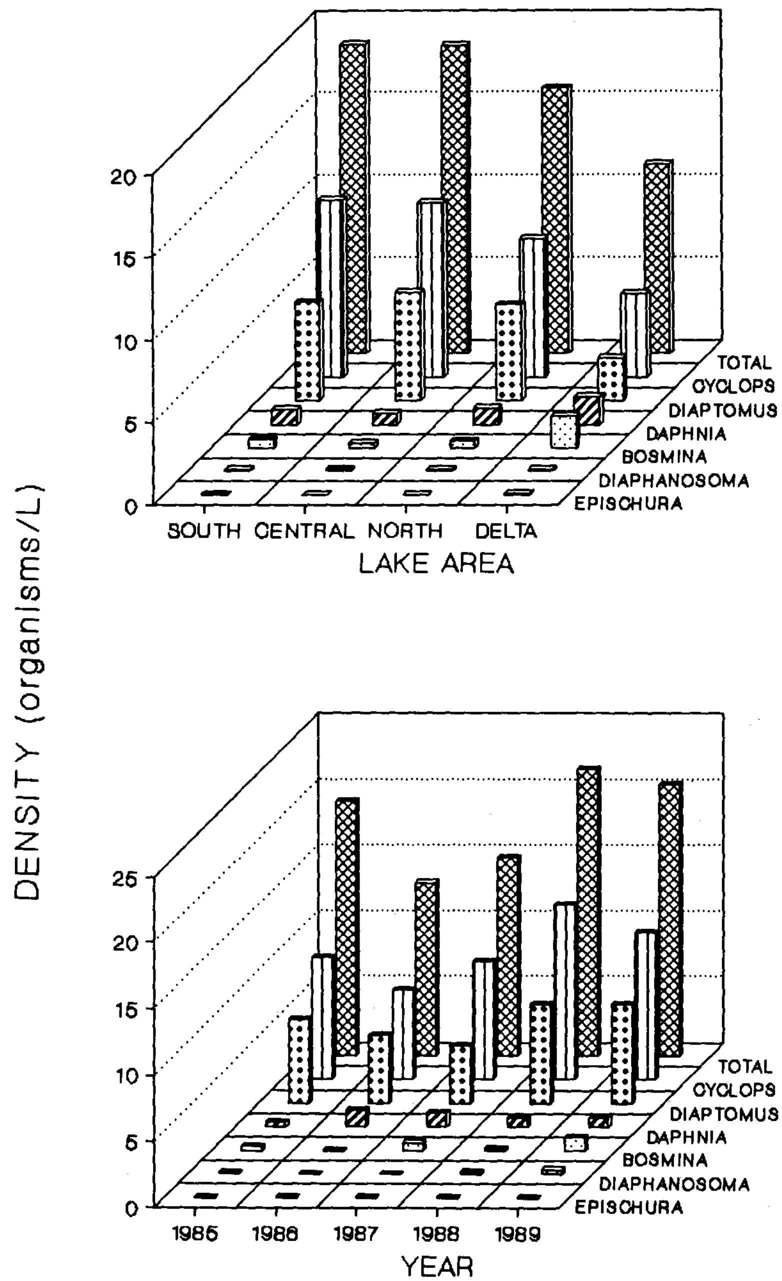

Figure 14. Mean zooplankton densities in Lake Pend Oreille, Idaho compared among lake sections and years.

organisms/L in August, 1985. Mean density of Daphnia during 1989 (0.709 organisms/L) was not significantly different (0.166<P<0.976) than estimated density for 1987 (1.077 organisms/L) or 1988 (0.701 organisms/L). Diaphanosoma density in 1989 (0.337 organisms/L) was significantly higher (P'0.10) than the previous four years, and peaked in August at 1.8 organisms/L, 240% higher than the previous high of 0.8 organisms/L in August, 1988. In general, zooplankton densities were similar (P>0.10) among northern, southern, and central sections of Lake Pend Oreille (Figure 14, Appendix C). Zooplankton densities in the Clark Fork River delta section were significantly lower (P(0.10) than other lake sections for Cyclops and Diaptomus, but significantly higher (P(0.10) for Bosmina and Daphnia (Figure 14, Appendix C).

The largest zooplankter in Lake Pend Oreille during 1989 continued to be Epischura, which averaged 1.9 mm long, followed by Daphnia thorata and D. galeata, which averaged 1.3 and 1.2 mm, respectively. Diaphanosoma and Diaptomus averaged 0.95 and 0.76 mm, respectively. Cyclops averaged 0.71 mm long, followed by Bosmina, the smallest zooplankter, at 0.37 mm. In general, zooplankton lengths for each genus did not vary significantly (P>0.10) among the last four years, or among months and lake sections (Figures 15 and 16, Appendix C).

Water Temperature and Transparency

Surface temperatures of Lake Pend Oreille from May through November, 1989, ranged from 7.5°C in November to 19.5°C in August (Figure 17). Thermal stratification began in July and extended through October. At peak stratification (August), the thermocline began at a depth of 12 m and average epilimnetic water temperature was 19.4°C.

Water transparency (Secchi disk) from May through October, 1989, ranged from 2.1 m in May to 12.8 m in August (Figure 18).

DISCUSSION

Kokanee Population Status

The kokanee population in Lake Pend Oreille during 1989 continued to respond favorably to enhancement efforts. Even though total abundance was 24% lower in 1989 than 1988, it was 80% higher than the population's low point in 1986, and the second highest since the completion of Cabinet Gorge Hatchery in 1985 (Appendix D). This decline can be partially attributed to low fry survival to fall 1989 and to the poorest survival of the age 1+ (1987 year-class) ever seen. During eight years of hatchery supplementation prior to completion of Cabinet Gorge Hatchery, relative contribution of hatchery fish to total kokanee abundance averaged 17% (Figure 19). After four years of operation, contribution from Cabinet Gorge Hatchery has increased to 41% of total kokanee abundance in Lake Pend Oreille. It is encouraging to note that this increase in relative

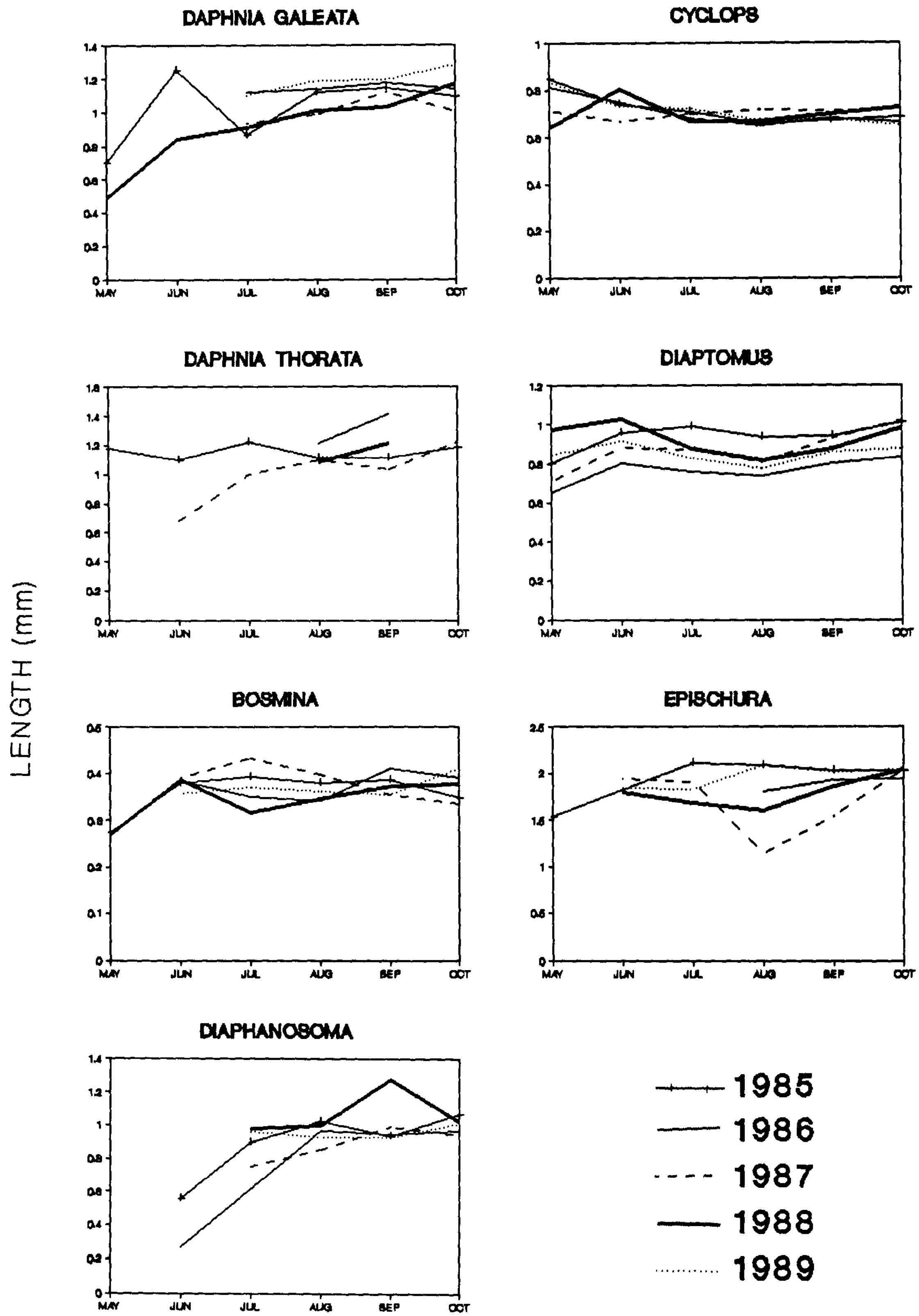

Figure 15. Temporal distribution of mean zooplankton lengths in Lake Pend Oreille, Idaho, May through October, 1985 through 1989.

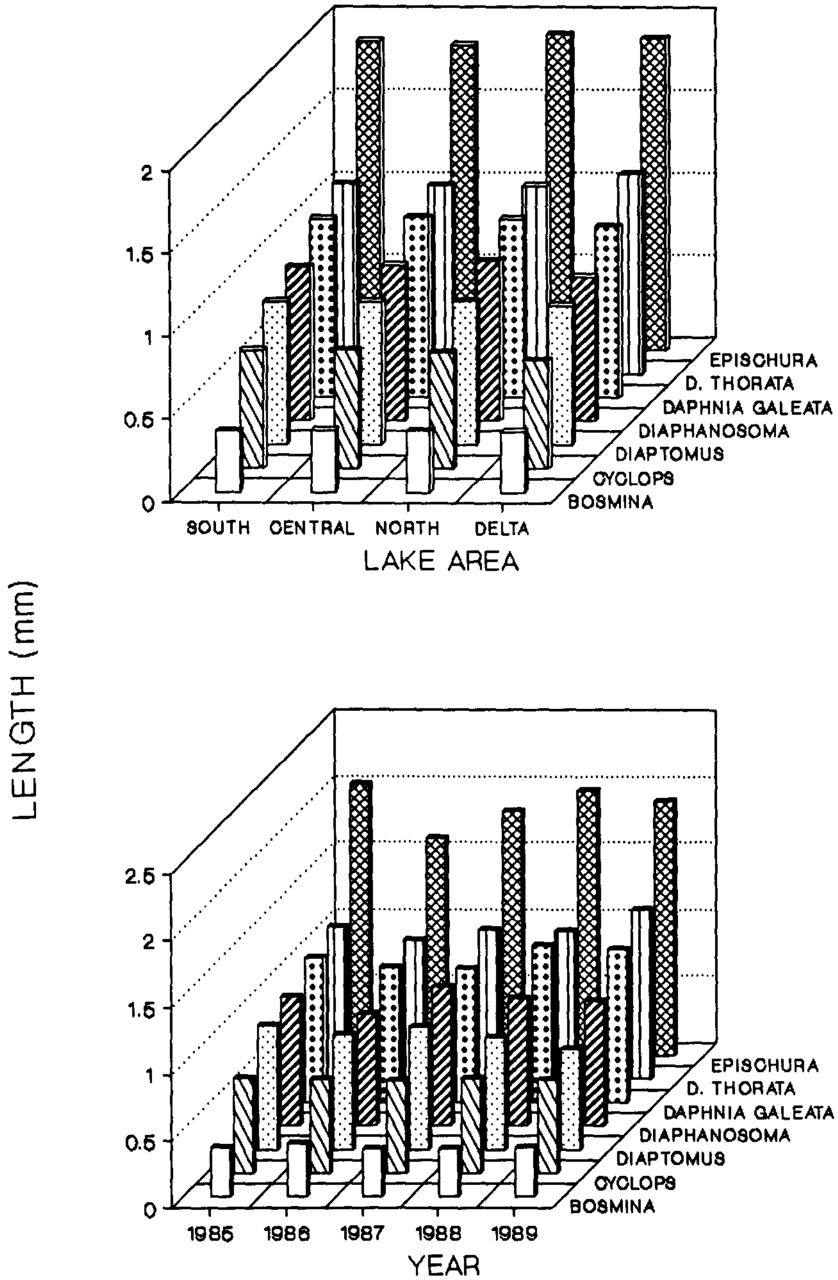

Figure 16. Mean zooplankton lengths in Lake Pend Oreille, Idaho, compared among lake sections and years.

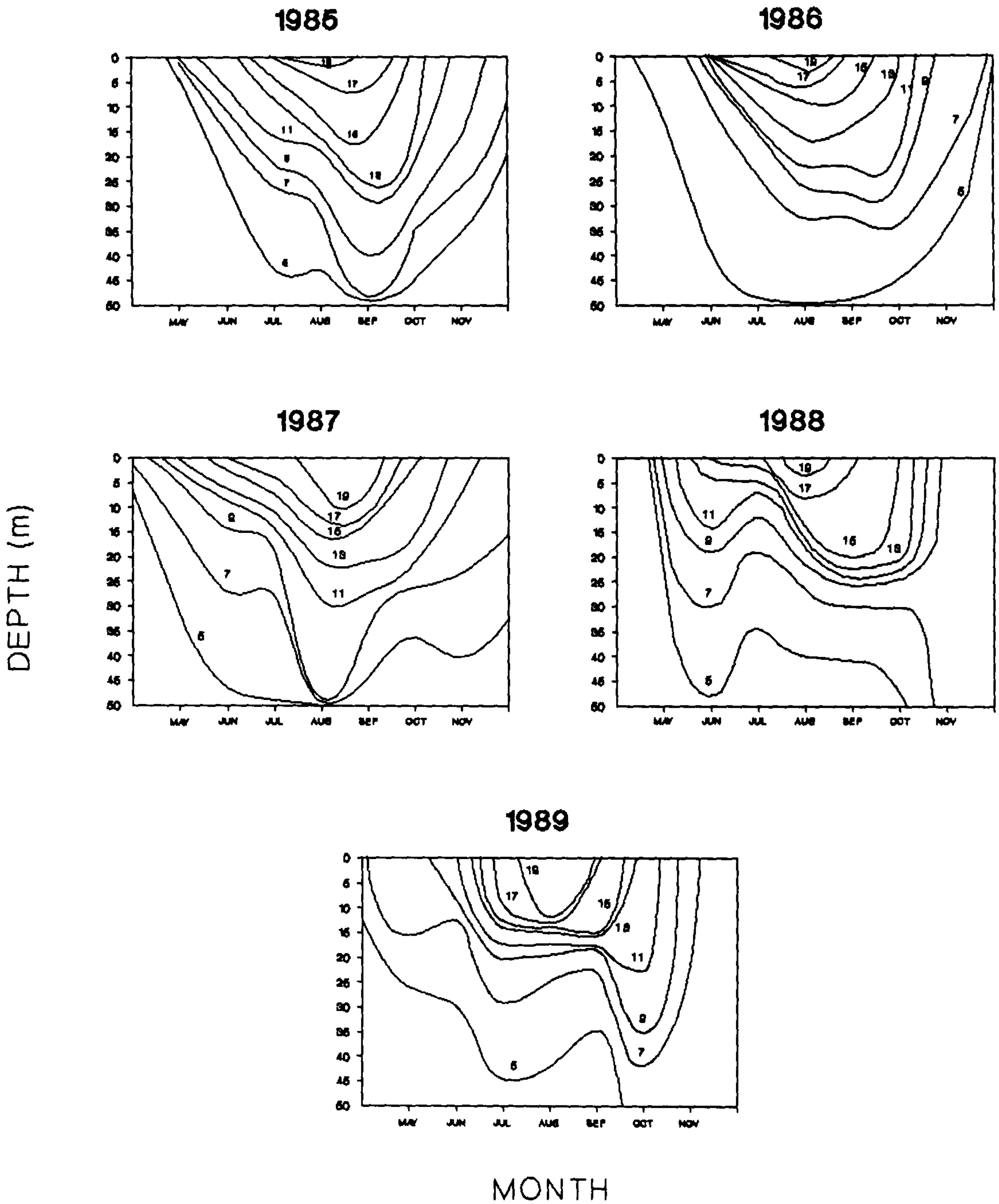

Figure 17. Distribution of thermal isopleths (°C) in the upper 50 m of Lake Pend Oreille, Idaho, May through November, 1985 through 1989.

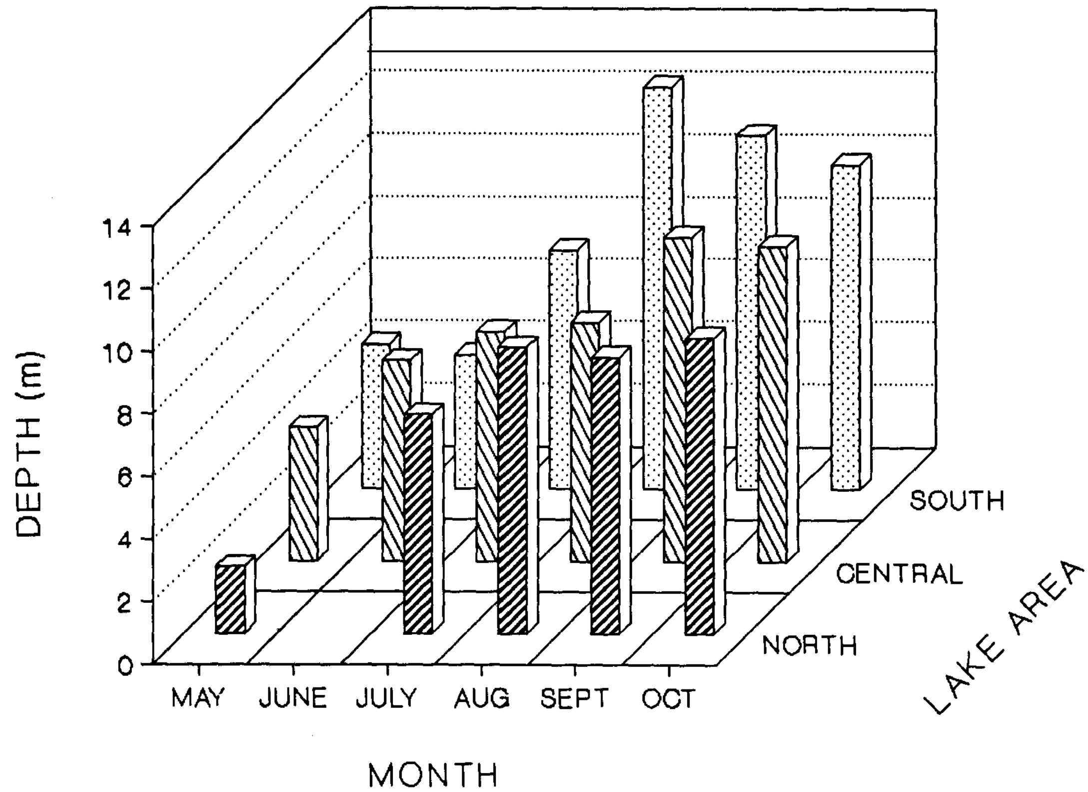

Figure 18. Water transparency (Secchi disk) in three sections of Lake Pend Oreille, Idaho, May through October, 1989.

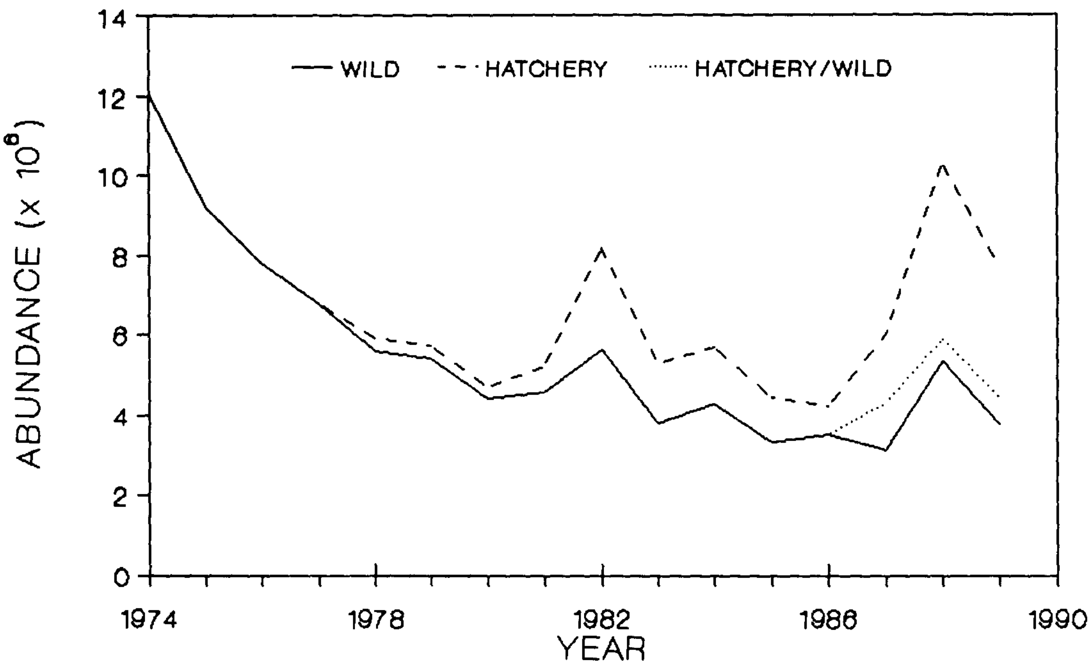

Figure 19. Relative hatchery contribution to total estimated kokanee abundance in Lake Pend Oreille, Idaho, 1974 through 1989. The hatchery-wild component represents contribution from naturally spawning kokanee of hatchery origin.

contribution is not an artifact of declining wild kokanee production, which has also increased an average of 36% since completion of the hatchery in 1985. The recent increase in kokanee abundance should begin to recruit to the fishery in 1990 (age 3+).

Survival of the 1987 year-class from autumn 1988 (age 0+) to fall sampling 1989 (age 1+) was 16%. This is approximately 75% lower than the previous nine-year average. The low estimated survival is particularly important because it affects the strongest year-class (7.31 million) since monitoring began in the mid-1970s. The low estimated survival may be attributed to either environmental conditions or sampling error. During 1989, sub-zero temperatures and high velocity winds were common in northern Idaho for a period in February. These severe conditions may have caused higher mortality rates among smaller kokanee fry. Size selective overwinter mortality may have favored larger kokanee fry, as mean length of age 1+ kokanee estimated from autumn trawling was 154 mm during 1989; 16 mm larger than in 1988. Analysis of age 1+ kokanee otoliths showed that 42% (N=19) were of hatchery origin, indicating that larger hatchery fry did not survive at a higher rate than smaller wild fry (62 mm vs. 45 mm average length, respectively) (Bowles et al. 1989). Age 1+ kokanee distribution in Lake Pend Oreille also may have contributed to the low estimated survival of age 1+ kokanee. Age 1+ kokanee typically display a clumped distribution in Lake Pend Oreille. Constraints of our sampling design may have biased our estimate of age 1+ kokanee abundance, as these fish tend not to be randomly distributed throughout the lake strata. Therefore, trawl hauls may miss the clumped distribution of that segment of the population and result in a lower estimate of that age-class.

Abundance of age 3+ and older kokanee, which comprise nearly 90% of the fishery (Bowles et al. 1986, 1987), was 18% higher in 1989 than 1988 and similar to 1987. Abundance of these older fish was 220% higher than the population's low point in 1984 (Figure 20, Appendix D). This increase in abundance resulted from high survival of older age-classes of kokanee. Based on an assumed exploitation rate of 25% (Bowles et al. 1987), the fishery may have supported a harvest of approximately 220,000 kokanee (10 fish/hectare) during 1989. This estimate represents approximately 30% of the restoration program goal to produce an annual catch of 750,000 kokanee (33 fish/hectare). Progress toward meeting this goal may become apparent in the fishery during 1991, when strong year-classes produced the previous two years enter the fishery. Based on year-class abundance observed during 1989, low age 1+ (1987 year-class) survival may dampen such benefits so that annual harvest during 1991 would be similar to the projected 1990 annual harvest of approximately 300,000 kokanee (13 fish/hectare). Based on typical survival and growth of age 1+ and older kokanee, annual harvest from Lake Pend Oreille may approach 500,000 kokanee (22 fish/hectare) by 1991. This projection assumes that age 1+ survival is similar to that observed since the completion of Cabinet Gorge Hatchery (45%) and that carrying capacity of Lake Pend Oreille is adequate to support increased kokanee abundance. If forage becomes limiting, projected benefits may be dampened as a result of reduced survival, growth, and age of maturity. We will continue to monitor these density dependent indicators of carrying capacity as older age-classes respond to enhancement efforts.

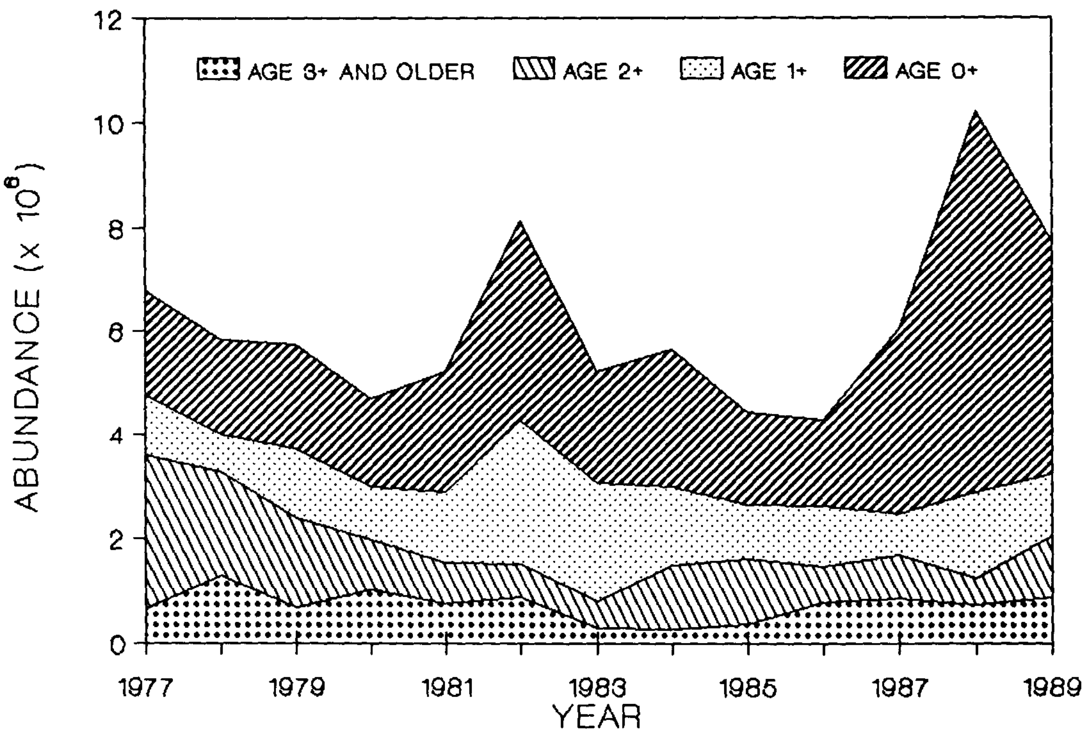

Figure 20. Total estimated abundance of four kokanee age groups in Lake Pend Oreille, Idaho, 1977 through 1989.

Although the fishery may respond dramatically to enhancement efforts by 1991, the outlook is not as encouraging for 1990. The effect of a weak 1985 year-class (age 3+ in 1989) is reduced as a relatively strong 1986 year-class (age 2+ in 1989) recruits to the fishery in 1990 (Figure 21, Appendix D), and may compensate enough to increase harvest by 36% to approximately 300,000 kokanee (13 fish/hectare) in 1990.

Fry Recruitment and Survival

Reduced kokanee abundance in 1989 was partially a result of lower fry recruitment. Fall abundance of age 0+ kokanee in Lake Pend Oreille decreased 38% from 1988 (320 fry/hectare) to 1989 (198 fry/hectare), but was still the second highest estimate since the late-1970s (Figure 21; Appendix D). Kokanee densities in other north Idaho lakes (no Mysis present) averaged 310 fry/hectare (N=10 years) in Coeur d'Alene Lake and 300 fry/hectare (N=8 years) in Spirit Lake (Horner et al. in press).

Enhanced recruitment in Lake Pend Oreille was evident for both wild and hatchery-reared kokanee fry during the past three years. Recruitment of wild fry was 37% lower in 1989 (99 fry/hectare) than 1988 (158 fry/hectare), while only slightly higher (8%) than average wild fry recruitment (91 fry/hectare) during the previous 11 years (Figure 22). Lower recruitment in 1989 was predominantly the result of a 22% decline in parental escapement resulting from a weak year-class and a low egg-to-fall fry survival. Wild fry survival was 2.2% in 1989, which is lower than both 1988 (3.3%) and 1987 (4.6%), but higher than the previous nine-year average (1.5%). Lower survival during the past year is attributed to decreased forage (cladoceran zooplankton) during late spring and early summer, a result of delayed thermal stratification, and may represent wild fry survival for a typical year. Although increased wild fry recruitment during the past three years in Lake Pend Oreille has greatly benefitted kokanee restoration efforts, conditions regulating wild fry survival remain largely uncontrollable. Rehabilitation efforts must continue to focus on hatchery supplementation to provide a stable recovery.

Kokanee fry production at Cabinet Gorge Hatchery over the past three years has dramatically increased hatchery fry survival and recruitment in Lake Pend Oreille. Hatchery fry during the past two years made up approximately 50% of total fry recruitment, which averaged less than 20% before 1988 (Figure 22). Contribution to recruitment biomass during 1989 was even more significant (80%) because hatchery fry were four times heavier than wild fry during fall trawling. Recruitment of hatchery fry was 40% lower in 1989 (99 fry/hectare) than 1988 (165 fry/hectare) as a result of a slightly smaller release (11.7 million vs. 13 million) and reduced post-release survival.

Hatchery fry survival from release date to fall sampling declined 34% from 1988 (29%) to 1989 (19%), but has generally increased since hatchery production began in 1986 (Figure 23). The success of fry releases in 1988 was very encouraging, but replication of those releases in 1989 (18%) showed how much variability may occur between years. Much of this variability may be attributed

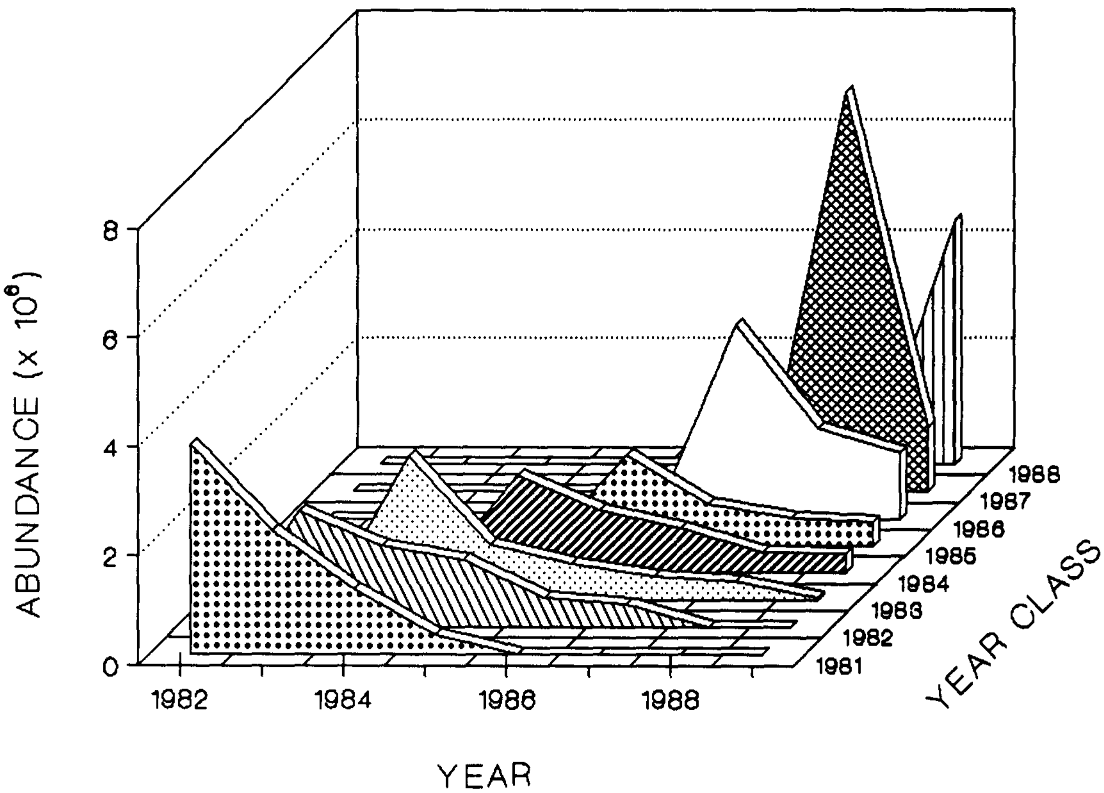

Figure 21. Comparative year-class strength of kokanee in Lake Pend Oreille, Idaho, from 1982 through 1989.

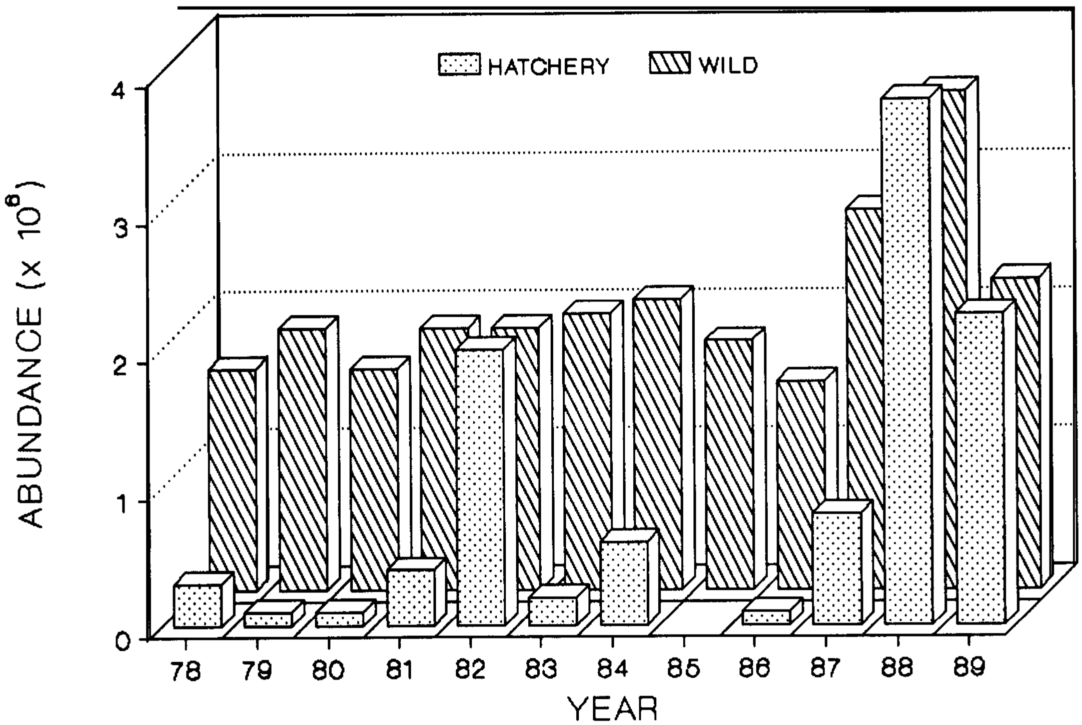

Figure 22. Total abundance of wild and hatchery-reared kokanee fry in Lake Pend Oreille, Idaho, during late summer, 1978 through 1989. Hatchery contribution in 1985 was not estimated.

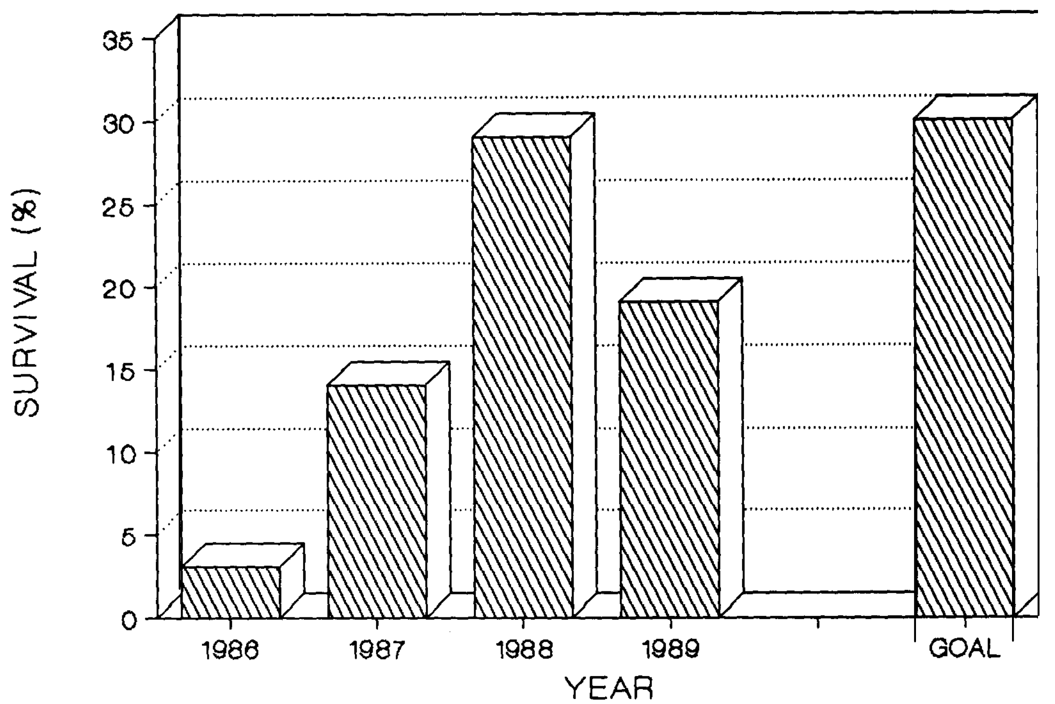

Figure 23. Estimated survival of kokanee fry during their first sum in Lake Pend Oreille, Idaho, following release from Cabi Gorge Hatchery, and survival goal established for the ko restoration program.

to the timing of thermal stratification of Lake Pend Oreille. Kokanee population modeling indicated fry survival from time of release to fall sampling must approach 30% to meet the fishery harvest goal of 0.75 million kokanee annually (Bowles et al. 1988). After one year of replication, hatchery fry survival can be expected to range between 20% and 30%. Initial improvements in survival resulted from releasing larger fry (50 mm) from Cabinet Gorge Hatchery than was possible from other hatcheries (30 mm) (Bowles et al. 1988). Survival was bolstered further in 1988 and 1989 by improving fry release strategies.

Release Strategies

Six fry release strategies were evaluated during 1989 to improve post-release fry survival and enhance spawning runs to Cabinet Gorge Hatchery and Sullivan Springs Creek. Five of the six releases were replicates of the 1988 releases, with one new release evaluated in 1989. Relative survival among release strategies within a year remained relatively constant between 1988 and 1989, but overall hatchery fry survival declined in 1989 (Figure 24). This decline can be partially attributed to decreased forage (zooplankton) during late spring and early summer as a result of delayed thermal stratification of Lake Pend Oreille and may represent what could be expected during a typical year. Although all release strategies were designed to maximize fry survival, highest priority was to enhance spawning runs to provide eggs for the recovery program.

Survival of kokanee fry released at Cabinet Gorge Hatchery improved dramatically in 1988 and 1989. Improving fry survival during emigration from Cabinet Gorge Hatchery to Lake Pend Oreille is critical to the establishment of a run back into the hatchery. Prior to 1988, fry were released mid-summer into Clark Fork River to coincide with increased food supply in Lake Pend Oreille. Success of these releases was often very poor as a result of low nighttime flows to aid emigration and abundant predators in the lower Clark Fork River and delta (Bowles et al. 1988). Two release strategies were evaluated during 1988 and 1989 to circumvent these constraints.

The first release occurred mid-June to coincide with spring runoff. High nighttime river flows during 1989 (>1,000 m^3/s; >36,000 ft^3/s) helped flush fry quickly (99% within one night) to Lake Pend Oreille and doubled survival over releases during lower flows (<570 m^3/s; <20,000 ft^3/s) for similar sized fry (50 mm). Survival of this release declined 33% from 1988 (27%) to 1989 (18%). Enhanced survival during emigration apparently compensated for lower food availability in Lake Pend Oreille at this time. Survival was also enhanced by a relative absence of predators in the lower Clark Fork River and delta following the release. Northern squawfish are common residents of the river (Jeppson and Platts 1959) and are effective predators of salmon emigrants (Brett and McConnell 1950; Foerster 1968). These predators were apparently spawning upriver and on lakeshores during mid-June and did not contribute substantially to fry mortality during emigration.

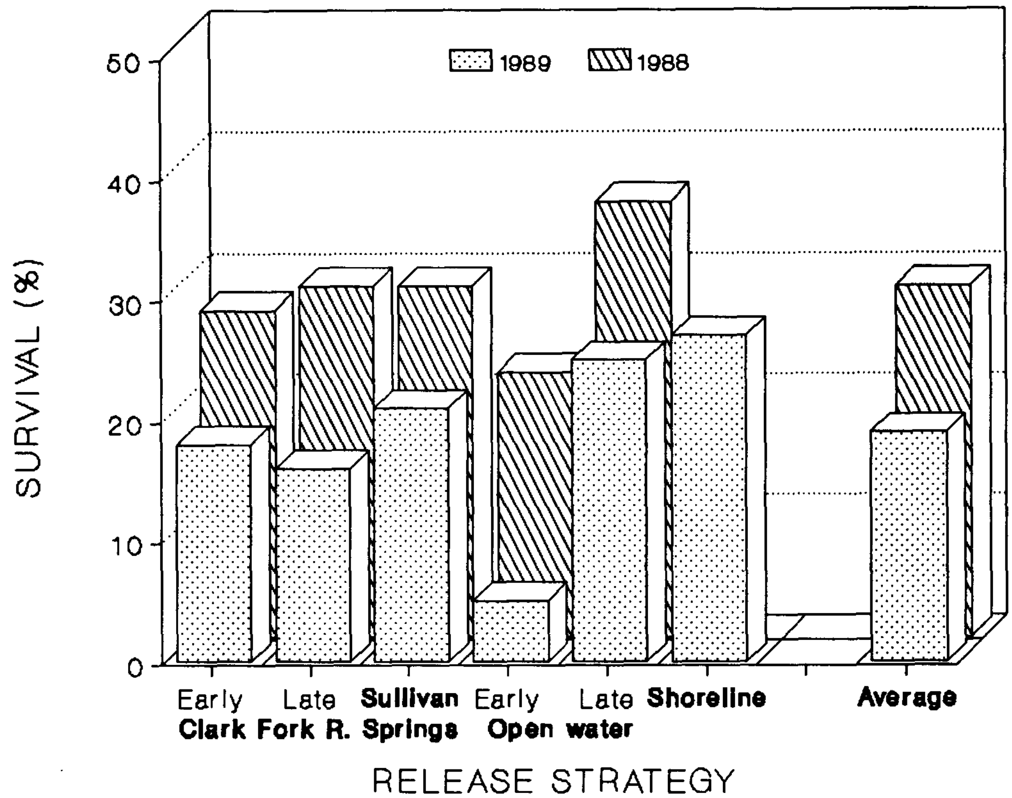

Figure 24. Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among six release strategies and years, 1988 vs. 1989.

The second Clark Fork River release occurred in July to coincide with thermal stratification and increased forage production in Lake Pend Oreille. Although fry were barged down Clark Fork River to avoid low flow problems of disorientation and predation, survival was not significantly different than the earlier fry release during high river flow in either 1988 or 1989. Although barging obviously improved survival of fry released below <570 m^3/s, (<20,000 ft^3/s) (22% vs. 10% survival), it is not known if barging affected the imprinting process. The effort and flow requirements for barging kokanee were also constraining. River flow must exceed 570 m^3/s (20,000 ft^3/s) for safe navigation, and a maximum of 150,000, 50-mm fry can be transported per barge. Full support of the Cabinet Gorge Hatchery run (approximately 8 million fry) by barging would require over 50 four-h trips each year. In light of these constraints, apparent success of the early season (high flow) release is very encouraging. The true success of these releases will be evaluated (from fin-clipped fish) when adults return to spawn at Cabinet Gorge Hatchery in 1991 and 1992.

Survival in 1989 (21%) was the second highest ever documented for fry released into Sullivan Springs Creek. Kokanee have been released annually into Sullivan Springs Creek since 1977 to enhance adult returns for egg-take. Documented survival from release to fall sampling in Lake Pend Oreille ranged from 7% to 18% and averaged 12% prior to 1988. Survival during the past two years has increased by an average of approximately 100% as compared to the previous 11 year average. This increase is probably a function of larger size of fry at release (50 mm) and date of release (mid-summer) when kokanee forage is more abundant.

The primary objective of open-water releases is to maximize fry survival and subsequent return-to-the-creel. It is unknown if these fish will contribute substantially to Cabinet Gorge Hatchery or Sullivan Springs Creek spawning runs, but may augment natural lakeshore spawners.

Fry released offshore during early summer had the lowest survival of any release strategy in both 1988 (22%) and 1989 (5%). Early summer Clark Fork River fry are released at approximately the same size (46 mm) and date, but survive, on the average, 33% better. Factors contributing to low survival of the early open-water release may include slightly smaller size (46 mm) than other releases (49-56 mm) and lower forage (cladoceran zooplankton) availability in that lake section during the time of release. Densities of cladoceran zooplankton (particularly Bosmina) in the lake section of the early open-water release were 83% less abundant in 1988 (0.42 organisms/L) and 94% less abundant in 1989 (0.16 organisms/L) at the time of fry release (mid to late June) than in the Clark Fork River delta; that area first used by fry released in Clark Fork River. Densities quickly rebounded in both years by mid-July. This absence of kokanee forage undoubtedly has a detrimental effect on the survival of early open-water releases. Fry released offshore during mid-summer survived better than those released in early summer (June) in both 1988 (36%) and in 1989 (25%), but survival declined by 31% in 1989. Factors contributing to high survival may include abundant forage (cladoceran zooplankton) and low predation due to schooling behavior of fry in Lake Pend Oreille and avoidance of riverine and shoreline predators. As a result of transportaion constraints, direct comparison of early vs. late open-water fry releases may be confounded because the early release was in the north end and the late release in the south end of Lake Pend Oreille. Evaluating differences between these release sites may be necessary before temporal comparisons can be made.

Fry released along the shore during mid-summer survived better (27%) than any other release in 1989. Factors contributing to high survival may include abundant forage (cladoceran zooplankton) and low predation due to schooling behavior of fry in Lake Pend Oreille. Shoreline predators may reduce potential benefits of such a release but was not apparent during 1989. The primary objective was to evaluate the survival of a less expensive release along shoreline. It is doutful these fish will contribute to Cabinet Gorge Hatchery or Sullivan Springs Creek spawning runs but may augment lakeshore spawners.

Approximately 7.5 million fry will be available for release into Lake Pend Oreille in 1990. Highest priority for fry releases are to support Clark Fork River and Sullivan Springs Creek runs. Based on 1988 and 1989 survival rates, a minimum of 3.5 million fry are needed for Clark Fork River (15% survival) and slightly less than 3 million fry for Sullivan Springs Creek (20% survival) to support escapement of 75,000 kokanee and 15 million eggs for each site. Surplus fry (approximately 1 million) could be used to replicate the south shoreline release in 1990.

Fry Marking

Marks used to distinguish release groups among trawl-caught kokanee fry continued to be successful. Wild fry and hatchery fry from six release strategies were differentiated using a combination of tetracycline and otolith marks. The tetracycline mark has proven successful for fry in Lake Pend Oreille since 1978 (Bowles et al. 1989). A date-of-release check on otolith microstructure was used in 1987, 1988, and 1989 to successfully differentiate hatchery release groups and wild fry. This is a passive mark induced environmentally during the transition from hatchery to lake residence and was identifiable up to 90 d after fry were released into Lake Pend Oreille.

Besides providing successful differentiation of kokanee fry, the date-of-release check on otolith microstructure was discernable on age 1+ kokanee otoliths during 1989. Although individual release groups were impossible to distinguish in older-age kokanee, this single mark helped differentiate hatchery vs. wild origin of age 1+ kokanee. During 1990, otoliths of age 2+ and older kokanee will be examined for this mark. How successful the kokanee rehabilitation effort is on Lake Pend Oreille ultimately depends on how production from Cabinet Gorge Hatchery contributes to the fishery and egg-take stations. By examining the otoliths of age 3+ and older kokanee, we may be able to evaluate hatchery contribution as hatchery fry move through the age-classes and recruit to the fishery and spawning population. Fin clipping of hatchery fry from various release strategies should continue to better evaluate the success of those releases to egg-take stations.

Examination of otoliths with ultraviolet light microscopy during 1990 will help determine if the tetracycline mark can be distinguished in kokanee fry collected during autumn trawling and after a year or longer in Lake Pend Oreille.

Manipulating water temperature to produce a single check on otoliths of kokanee fry did not provide a reliable mark during 1988 (Bowles et al. 1989). Tempering constraints at Cabinet Gorge Hatchery resulted in very low water temperature (2°C), when higher water temperature (8-10°C) during the marking period is desirable. Although these constraints preclude marking kokanee fry at Cabinet Gorge Hatchery, thermally marking kokanee embryos may be a viable alternative. Incubation temperatures are commonly 10°C, and less water is required. Thermal marks have been made successfully on otoliths of salmon and char embryos (Brothers 1985; Volk et al. 1987).

Kokanee Forage Availability

Even though total zooplankton densities in 1989 were similar to 1987 and 1988 during May and June, cladoceran zooplankton production did not begin until later. Changes in early season zooplankton production, particularly cladoceran, is regulated predominantly by water temperature and thermal stratification. Wild kokanee fry typically emerge in June when fry are ineffective predators on fast-moving copepods but can effectively utilize the slower-moving cladocerans (Rieman and Bowler 1980). Decreased cladoceran abundance during early summer made these important forage items unavailable to wild fry during their critical postemergent stage of development and, therefore, reduced survival of wild kokanee fry. Cladoceran production during 1989 may be more typical than either 1987 or 1988.

Establishment of Mysis in Lake Pend Oreille has greatly reduced cladoceran production during early summer (Rieman and Falter 1981; Bowles et al. 1987). Mysids prey heavily on cladoceran zooplankton (Bowers and Vanderpoeq 1982) and are most effective predators prior to thermal stratification of the lake (Rieman and Falter 1981; Bowles et al. 1988). After stratification, Mysis are spatially segregated from these zooplankton by warm (>14-18°C) epilimnal waters (Beeton 1960; Nero and Davies 1982; Nero and Sprules 1986). During 1989, thermal stratification of Lake Pend Oreille occurred later than the previous year, and coupled with relatively similar mysid density (Figure 25), resulted in a lower survival of wild fry.

Annual fluctuations in Mysis abundance are apparently common in Lake Pend Oreille (Figure 25) and have been documented in other lakes containing mysids (Lasenby et al. 1986). The impact of these fluctuations on kokanee fry survival is of lesser importance than annual changes in timing and extent of thermal stratification of Lake Pend Oreille. We will continue to monitor zooplankton and mysid populations to better define their relationship and impact on kokanee survival.

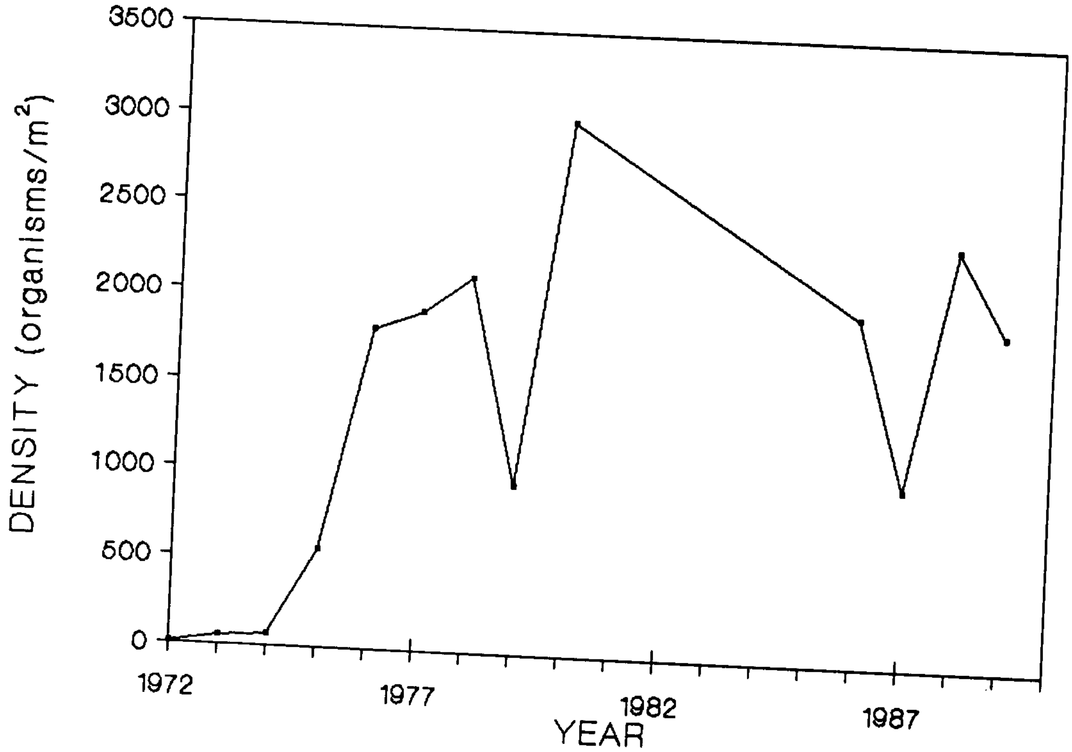

Figure 25. Estimated density of *Mysis* in Lake Pend Oreille, Idaho.

Spawning

Spawner escapement increased 14% from 1988 to 1989. This may be attributed to higher survival of older age-classes of kokanee. However, egg-take during 1989 was approximately 35% lower and was the result of environmental conditions and low year-class strength. Potential egg deposition was similar to 1988 as a result of less fecund (426 eggs/female) spawners. A trend toward older, more fecund and larger mean spawner lengths (Figure 26) has been evident in recent years. As kokanee become more numerous in Lake Pend Oreille, age at maturity and fecundity are expected to stabilize and possibly decline. These trends will be monitored closely to help establish hatchery production levels that will optimize size and abundance of kokanee in the fishery.

Spawner escapement to Sullivan Springs was 17% of total escapement in 1989 as compared to 15% during 1987 and 1988 and has varied from 1.7% to 28% during the past 13 years. This slightly higher percentage of total escapement may be attributed to spawned-out males re-entering the Sullivan Springs Creek trap after being flushed from the creek following several flood events. Spawned-out males are more difficult to detect than females, and a small percentage of the males may have been enumerated twice. This is further evident by the high percentage of males (65%) spawned at the trap. Depending on weather conditions (Bowles et al. 1987), escapement to Sullivan Springs should remain at approximately 15% of total escapement during the next two years. Although Sullivan Springs fry-to-adult "return" rates averaged over 10% during the early 1980s, rates have remained under 5% since the mid-1980s (Appendix E). Based on estimated annual mortality, these latter rates are more indicative of actual fry-to-adult returns. Higher "return" rates in the early 1980s were probably biased by wild kokanee utilizing Sullivan Springs.

Egg-take at Sullivan Springs was 34% lower in 1989 than 1988, and 44% lower than 1987 as a result of two weak year-classes (1984 and 1985) maturing. The number of kokanee spawning at Sullivan Springs may increase slightly during 1990 with the maturing of a relatively strong year-class (1986 year-class; age 3+) and may provide 10 million eggs. An additional 5 million eggs will be needed for 1990, and alternative egg sources should be developed. This is necessary to support the rehabilitation program and avoid large fluctuations in year-class strength. Potential local sources include Spring Creek, Clark Fork River, and Lake Coeur d'Alene. By 1991, egg-take from Sullivan Springs should rebound to a minimum of 15 million eggs as estimated from the low age 1+ survival of 16%. If the age 1+ kokanee survived at a higher rate, then more eggs will be available. The potential effect of a low age 1+ survival would be more dramatic in 1992, when the 1987 year-class recruits as age 4+ kokanee. Better projections will be available after autumn trawling in 1990.

Although spawners have been abundant in Clark Fork River during 1987, 1988, and 1989, few have volunteered into the Cabinet Gorge Hatchery fish ladder and trap. Spawning at Cabinet Gorge Hatchery has provided less than 2 million eggs since completion of the hatchery in 1985. Less than 1,000 spawners (approximately 0.25 million eggs) returned in 1989 from the first fry released at the hatchery in 1986 (age 3+ in 1989) and from fish which volunteered into

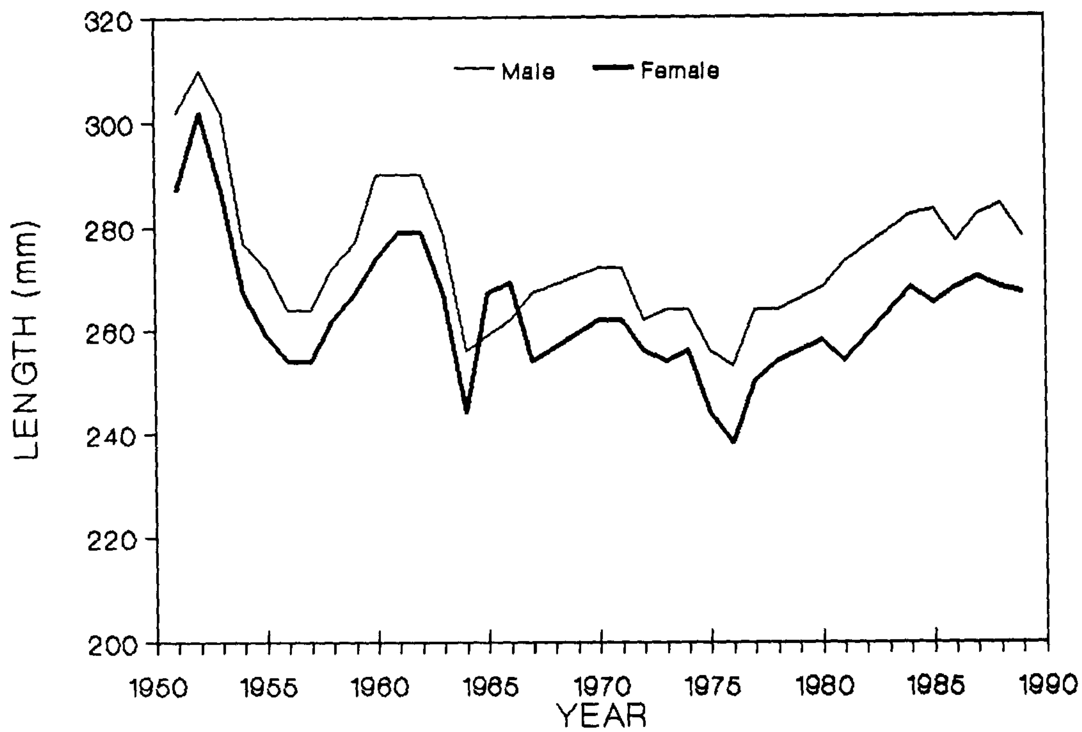

Figure 26. Mean total length of male and female kokanee spawners from Lake Pend Oreille, Idaho.

the Cabinet Gorge Hatchery ladder and trap. The projected run was small because fry released in 1986 were not imprinted on morpholine and fry survival was low (3%) (Bowles et al. 1987). Escapement should improve slightly in 1990 (22,000 spawners, 4 million eggs) from enhanced fry survival and morpholine imprinting. Contribution from adult returns to Cabinet Gorge Hatchery will continue to be low until 1991, when the success of fry releases in 1988 may increase escapement to Cabinet Gorge Hatchery to approximately 22,000 spawners and 9 million eggs.

These projections assume that mortality, fecundity, and age at maturity remain relatively static as kokanee abundance increases in Lake Pend Oreille and that adults will target on the morpholine attractant to insure migration up the Cabinet Gorge Hatchery fish ladder. These parameters are being monitored carefully, and projections will be modified as necessary.

RECOMMENDATIONS

1. A minimum of 3.5 million fry should be released in Clark Fork River each year to provide a potential egg supply of at least 15 million eggs for Cabinet Gorge Hatchery. Fry releases into Clark Fork River should coincide with the end of spring runoff during at least 850 m^3/s (30,000 ft^3/s) nighttime flows to insure optimal fry survival and imprinting.

2. Approximately 3 million fry should be released into Sullivan Springs Creek each year to maintain a potential egg supply of at least 15 million eggs. Fry releases into Sullivan Springs Creek should not occur before thermal stratification of Lake Pend Oreille (typically mid-July) to insure adequate forage.

3. Release approximately 1 million fry along the south shoreline in 1990 to replicate results and determine annual variability in survival.

4. All fry released at Cabinet Gorge Hatchery and Sullivan Springs Creek should be imprinted with morpholine which will be used as an adult attractant. A representative portion of fry (>40,000 fish) released in Clark Fork River and Sullivan Springs Creek should be fin-clipped to evaluate adult return rates.

5. Average fry length at the time of release should be 50 $\pm$ 2 mm for production fish.

6. Evaluate the reliability of otoliths for discerning the date-of-release mark in age 1+ and older kokanee.

ACKNOWLEDGEMENTS

Sue Morrison assisted with various sampling and analysis activities. Eric Johnson provided assistance during trawling on Lake Pend Oreille. Personnel from Cabinet Gorge and Clark Fork Hatcheries were responsible for spawning activities and provided valuable assistance and advice during development and implementation of fry release strategies. Ed Schriever and his staff at Cabinet Gorge Hatchery also constructed an experimental barge for transporting fry down Clark Fork River and were responsible for all fry marking activities.

Equipment, personnel, and expertise provided by George Guedel and his staff at the Naval Acoustic Research Detachment, US Department of Navy, and by Richard Hansen helped insure the success of kokanee fry releases into southern Lake Pend Oreille. Personnel from the Army Corps of Engineers at Albeni Falls Dam removed log booms in the lower Clark Fork River to insure safe navigation while barging kokanee fry.

Roger Woodworth and Gary Stockinger from WWP were very cooperative and provided valuable advice in developing the fry release study. WWP provided the maximum possible flows during fry releases into the Clark Fork River. Fred Holm from BPA provided technical and administrative advice throughout the year. Tim Cochnauer and Virgil Moore reviewed the draft report.

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APPENDICES

Appendix A. Kokanee age class density (fish/hectare) in Lake Pend Oreille during late summer, 1989. A 90Z error bound is listed with each estimate.

Age class	Origin	Lake section 1	2	3	4	5	6	Total
0+	Hatchery (total)	68.6±22.1	123.6±31.1	110.8±46.2	151.5±35.7	55.3±27.4	81.0±39.0	99.2±14.8
	Clark Fork River							
	Early summer[a]	6.8±2.4	15.1±4.0	25.4±9.1	29.9±6.6	27.7±15.2	51.5±22.9	28.2±5.9
	Mid-summer[b]	0	0	6.0±3.5	14.9±5.9	3.9±3.9	11.7±7.7	6.8±2.2
	Sullivan Springs[c]	7.0±1.7	32.0±10.0	41.2±15.8	85.1±18.1	19.8±10.8	11.1±5.1	33.1±4.8
	Open Water							
	Early summer[d]	0	4.6±1.4	0	3.7±1.5	0	5.9±3.9	2.6±0.9
	Mid-summer[e]	20.2±7.3	48.0±14.9	21.7±8.5	10.5±2.2	4.0±2.2	0	15.9±2.8
	Shoreline[f]	34.7±23.7	23.9±6.4	16.5±12.1	7.4±3.0	0	0	12.4±4.0
	Wild	107.5±36.7	132.5±18.4	128.2±21.5	130.9±22.0	45.0±17.0	59.0±34.1	98.7±11.2
	Wild & Hatchery	176.1±42.7	256.1±42.1	239.0±63.4	282.4±55.9	100.3±42.9	139.9±71.6	197.9±24.0
1+	Wild & Hatchery	38.5±20.8	10.5±6.3	10.1±6.1	24.8±19.8	36.8±14.7	149.2±72.9	51.5±17.0
2+	Wild & Hatchery	190.4±104.2	13.5±7.3	14.1±5.2	27.4±14.1	40.9±10.3	50.2±18.5	53.0±15.5
3+	Wild & Hatchery	75.3±52.2	11.2±8.2	6.0±3.5	6.0±3.1	16.7±6.8	14.1±9.5	19.9±7.8
4+	Wild & Hatchery	18.7±11.8	16.5±9.9	15.5±9.0	12.1±6.4	14.6±9.9	20.6±13.6	16.5±4.4
5+	Wild & Hatchery	0.4±0.4	1.2±1.1	2.2±1.6	2.3±1.7	2.0±1.9	2.6±2.5	1.9±0.8
Total	Wild & Hatchery	499.4±252.3	309.2±42.3	287.0±74.7	355.0±65.4	211.3±58.4	376.8±85.0	340.7±39.4

[a] Hatchery-reared kokanee fry released into Clark Fork River.
[b] Hatchery-reared kokanee fry barged down Clark Fork River and released into Lake Pend Oreille.
[c] Hatchery-reared kokanee fry released into Sullivan Springs Creek.
[d] Hatchery-reared kokanee fry released offshore northern Lake Pend Oreille.
[e] Hatchery-reared kokanee fry released offshore southern Lake Pend Oreille.
[f] Hatchery-reared kokanee fry released from shore southern Lake Pend Oreille

Appendix B. Maximum single late-run (early run included for Trestle Creek) kokanee counts made during the 1973-1978 and 1985-1989 spawning seasons on Lake Pend Oreille and its tributaries, excluding the Granite Creek drainage.

Area	Maximum single counts										
	1973	1974	1975	1976	1977	1978	1985	1986	1987	1988	1989
Lakeshore											
Bayview	17,156	3,588	9,231	1,525	3,390	798	2,915	1,720	1,377[c]	2,100	875
Farragut	0	0	0	0	0	0	--	10	0	4	--
Idl•ewild Bay	0	25	0	0	0	0	--	--	--	--	--
Lakeview	200	18	0	0	25	0	4	127	59	0	0
Ellisport Bay and Hope	436	975	0	0	0	0	0	0	0	--	--
Trestle Creek Resorts	1,000	2,250	0	115	75	138	2	35	350	2	2
Sunnyside	25	0	0	0	0	0	0	0	0	--	--
Fisherman Island	0	75	0	0	0	0	--	--	--	--	--
Anderson Point	0	50	0	0	0	0	--	--	--	--	--
Camp Bay	617	0	0	0	0	0	0	0	0	--	--
Garfield Bay	400	20	0	0	0	0	0	6	0	35	--
Subtotal	19,834	7,001	9,231	1,640	3,490	936	2,921	1,898	1,786	2,141	877
Percent of Total	62%	25%	64%	33%	40%	19%	32%	10%	20%	14%	19%
Tributaries											
South Gold Creek	1.875	1.050	440	0	30		235	1.550	2.761.	2.390	830
North Gold Creek	1,383	1,068	663	130	426	--	696	1,200	2,750	880	448
Cedar Creek	267	44	16	11	0	0	--	--	--	--	--
Johnson Creek	0	1	0	0	0	0	--	182	0	0	0
Twin Creek	0	135	1	0	0	0	5	0	0	0	0
Mosquito Creek	503	0	0	0	0	0	--	--	--	--	--
Clark Fork River	3,520	6,180	0	--	--	--	--	--	--	--	--
Lightning Creek (Lower)	500	2.350	995	2.240	1.300	44	127	165	75	6	--
Spring Creek	4,025	9,450	3,055	910	3,390	4,020	5,284	14,000	1,500[d]	9,000	2,400
Cascade Creek	--	--	--	--	--	--	--		0	119	48
Trestle Creek	18	1,210	15	0	40	0	0	0	0	0	0
Trestle[a]	1,100	217	14,555	1,486	865	1,589	208	1,034	410	422	466
Garfield Creek	0	25	0	0	0	0	--	1	0	0	0
Subtotal	12,091	21,513	5,185	3,291	5,186	4,046	6,347	17,098	7,086	12,698	3,726
Percent of Total[b]	38%	75%	36%	67%	60%	81%	68%	90%	80%	86%	81%
Total[b]	31,925	28,514	14,416	4,931	8,676	5,000	9,268	18,996	8,872	14,839	4,603

[a] Maximum single early-run count of kokanee spawners.
[b] Excluding early-run kokanee spawners in Trestle Creek.
[c] Represents a partial count only because heavy wave action kept spawners offshore and uncountable.
[d] Count made third week of December because low flows in Lightning Creek resulted in a complete passage barrier during early December.

Appendix C. Statistical comparisons (ANOVA) of zooplankton densities and lengths from 1985 to 1989 among lake sections and years, Lake Pend Oreille, Idaho. Lake section abbreviations are: Southern = s, Central = C, Northern = N, Clark Fork River delta = D. Nonsignficant (P>0.10) contrasts are delineated by a common line under each contrast. Estimated density and length increase from left to right for lake sections and years.

	P level for main effect		Main effect contrasts (P>0.10)	
Zooplankter	Lake section	Year	Lake section	Year
		Density		
Cyclops	0.000	0.000	D N <u>C S</u>	86 <u>87 85</u> 89 88

Diaptomus	0.000	0.000	D <u>N S C</u>	<u>87 86</u> 85 <u>89 88</u>
Epischura	0.001	0.001	<u>N C S</u> D	<u>86 88 89</u> <u>87 85</u>
Bosmina	0.000	0.000	<u>C N S</u> D	<u>86 88 85</u> 87 89

Diaphonosoma	0.859	0.000	<u>S D N C</u>	<u>86 87 85</u> 88 89

Daphnia	0.015	0.027	<u>C S N</u> D	<u>85 88 89 87 86</u>

Total	0.000	0.000	D N <u>C S</u>	<u>86 87</u> <u>85 89 88</u>
		Length		
Cyclops	0.000	0.586	D <u>N S C</u>	<u>87 86 89 88 85</u>
Diaptomus	0.349	0.000	<u>D S C N</u>	89 <u>88 86</u> <u>87 85</u>
Epischura	0.649	0.000	<u>C S D N</u>	86 <u>87 89</u> 88 85

Bosmina	0.700	0.002	<u>D S N C</u>	<u>87 88 85</u> 89 86

Diaphanosoma	0.180	0.002	<u>D S C N</u>	86 <u>89 88 85</u> 87

Daphnia galeata	0.299	0.000	<u>D N S C</u>	<u>87 86</u> 85 <u>89 88</u>
D. thorata	0.779	0.024	<u>NC S D</u>	<u>86 88 87 85</u> 89

Appendix D. Estimated year class abundance (millions) of kokanee made by midwater trawl in Lake Pend Oreille, Idaho, 1979 through 1989. The two oldest age classes were combined for estimates from 1979 through 1985.

Year class	Year estimated 1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
1988	4.48										
1987	1.17	7.31									
1986	1.20	1.66	3.55								
1985	0.45	0.51	0.78	1.66							
1984	0.37	0.38	0.84	1.15	1.79						
1983	0.04	0.35	0.43	0.68	1.03	2.63					
1982			0.42	0.54	1.24	1.51	2.14				
1981				0.24	0.37	1.21	2.28	3.84			
1980						0.27	0.50	2.77	2.31		
1979							0.29	0.64	1.36	1.69	
1978								0.87	0.79	1.00	2.01
1977									0.74	0.96	1.31
1976										1.03	1.70
1975											0.67
Total	7.71	10.21	6.01	4.27	4.47	5.62	5.21	8.12	5.20	4.68	5.69
Density (No./ hectare	341	450	266	189	198	249	230	358	230	207	251

Appendix E. Kokanee spawned from Sullivan Springs Creek from 1976 through 1989, number of eggs collected, subsequent fry released into Sullivan Springs and adult return rate.

Year Class	Kokanee spawned	Eggs collected	Fry released following year[a]	Estimated returning adults from hatchery releases and year	returned	Adult returns as a percent of fry released
1976	10,200	913,000	757,700	55,500 42,200	(1980) (1981)	12.96
1977	17,560	2,040,000	1,598,800	135,300 29,000	(1981) (1982)	10.28
1978	16,875	1,400,000	1,745,700	118,000 58,000	(1982) (1983)	10.08
1979	12,005	1,451,400	1,081,400	42,000 75,660	(1983) (1984)	10.88
1980	48,760	4,186,700	2,219,800	54,340 46,810	(1984) (1985)	4.56
1981	112,820	11,653,000	2,487,800	27,935 20,060	(1985) (1986)	1.93
1982	115,850	11,432,900	2,875,589	22,170 77,773	(1986) (1987)	3.48
1983	79,850	6,320,000	3,214,512	5,854 48,444	(1987) (1988)	1.69
1984	122,000	15,000,000	3,428,279	12,111	(1988)	
1985	75,500	10,600,000	1,594,731			
1986	42,230	7,337,000[b]	2,847,345			
1987	83,627	16,600,000[c]	5,138,800			
1988	60,555	14,058,000[d]	3,538,000			
1989	70,600	9,372,000[e]				

[a] Additional fry were released in other areas.

[b] An additional 1.76 million eggs were collected from Spring Creek and the Clark Fork River, bringing the total egg take to 9.1 million.

[c] An additional 0.61 million eggs were collecte' from Clark Fork River, bringing the total egg take to 17.22 million.

[d] An additional 0.10 million eggs were collected from Clark Fork River, bringing the total to 14.16 million.

[e] An additional 0.21 million eggs were collected from Clark Fork River, bringing the total to 9.58 million.

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